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AN/SQS-23 (PAIR) SONAR LETTER REPORT.(U)

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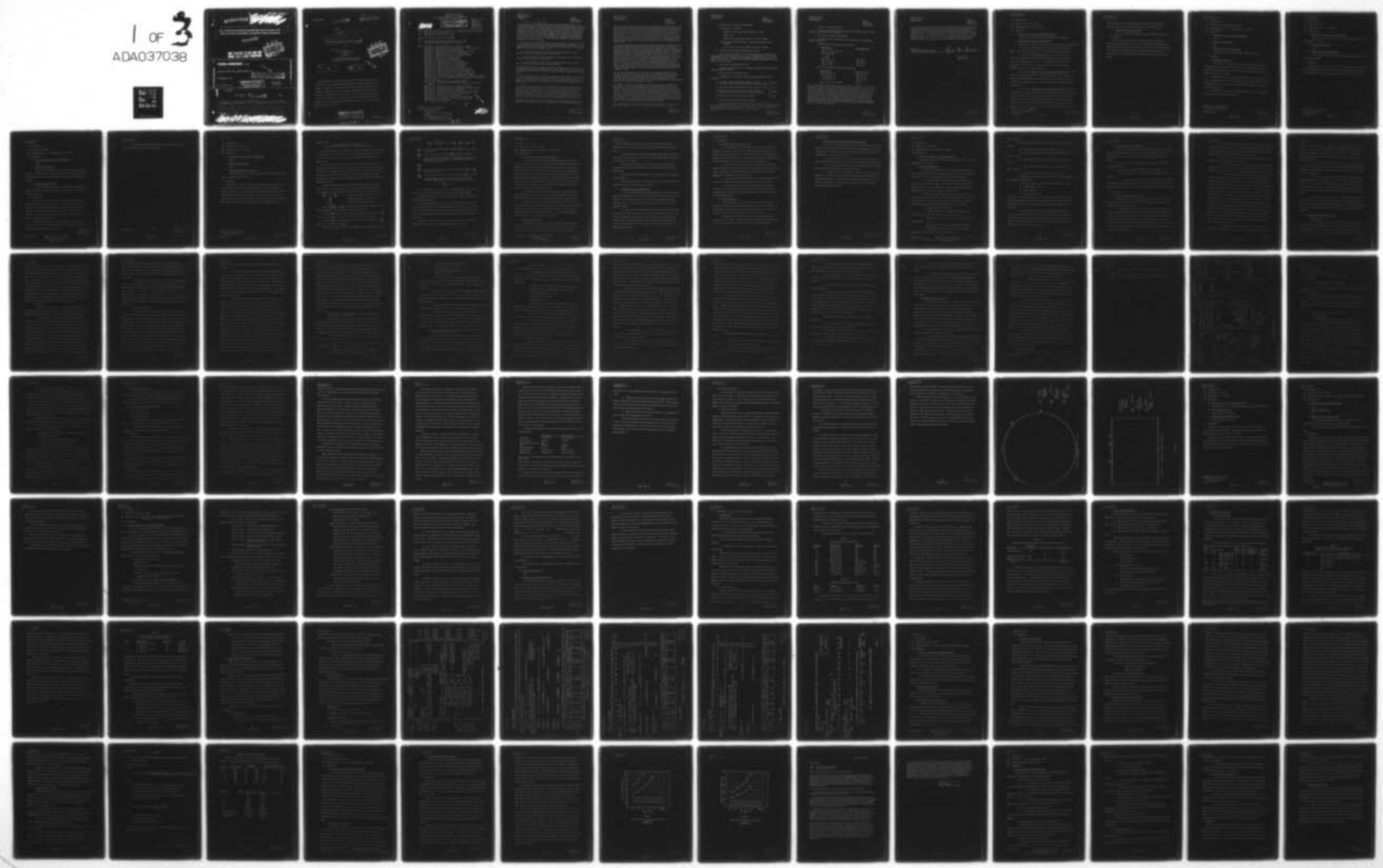

1 OF 3

ADA037038

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA

This is a working paper giving tentative information about some work in progress at NEL. If cited in the literature the information is to be identified as tentative and unpublished.

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TECHNICAL MEMORANDUM TM-1050

NEL/Technical Memorandum

AN/SQS-23 (PAIR) SONAR LETTER REPORT (U)

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22 September 1965

S 27-20(8573)
NEL J71471

R. D. Isaak et al

NEL/Technical Memorandum 1050

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NEL Technical Memorandum
Number 1050

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AN/SQS-23 (PAIR) Sonar Letter Report. (U)

by

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R. D. Isaak, et al
Code 2140

U. S. Navy Electronics Laboratory
San Diego, California 92152

11

22 Sep 65

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267 p.

This technical memorandum represents a portion of the work being done on NEL Problem J714, AN/SQS-23 Performance and Integration Retrofit (PAIR) Program. It should not be construed as a formal report as its primary intent is to present some of the problems confronting project personnel and some of the preliminary conclusions. While it was originally published in a different form, it is now being included in the technical memorandum series for sake of documentation uniformity and control. Limited outside distribution is intended.

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U. S. NAVY ELECTRONICS LABORATORY
SAN DIEGO, CALIFORNIA 92152

IN REPLY REFER TO:
S27-20
Task 8573
(NEL J71461)
Ser 2140-03
SEP 22 1965

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[redacted]

From: Commanding Officer and Director, U. S. Navy Electronics Laboratory, San Diego, California 92152
To: Chief, Bureau of Ships (Code 1633)

Subj: AN/SQS-23 PAIR Sonar Letter Report

Ref: (a) BUSHIPS ltr 9674 ser 1633-796 of 13 Jul 1965
(b) NEL ltr 3920 ser 3100-22 of 4 Aug 1965

Encl: (1) Task 1 - Passive Arrays; Dr. C. J. Burbank (CONF)
(2) Task 2 - Beam Forming and Preamps; Dr. C. J. Burbank (CONF)
(3) Task 3 - Dome; Dr. C. J. Burbank (CONF)
(4) Task 4 - PADLOC, AN/SQR-13; Dr. C. J. Burbank (CONF)
(5) Task 5 - Calibration; Dr. C. J. Burbank (CONF)
(6) Task 6 - Quieting, Noise; Dr. C. J. Burbank (CONF)
(7) Task 7 - Interface; J. Reardon (CONF)
(8) Task 8 - Display; J. Reardon (CONF)
(9) Task 9 - Simulation; J. Reardon (CONF)
(10) Task 10 - Microcircuits; J. Reardon (CONF)
(11) Task 11 - Operating Modes; W. E. Klund (CONF)
(12) Task 12 - Stabilization; H. J. Klee (CONF)
(13) Task 13 - Active Array; H. J. Klee (CONF)
(14) Task 14 - Wave Period Processor; H. J. Klee (CONF)
(15) Task 15 - Signal Processing; W. E. Klund (CONF)
(16) Task 16 - EMEC Transmitter Portion; H. J. Klee (CONF)
(17) Task 17 - Instrumentation; D. C. Lookingbill (CONF)
(18) Task 18 - Performance Memory Equipment; D. C. Lookingbill (CONF)
(19) Task 19 - Performance Monitor and Fault Location, D. C. Lookingbill (CONF)
(20) Task 20 - Classification; J. Reardon (CONF)
(21) Task 21 - Performance and Operations Analysis; Dr. W. Watson (CONF)
(22) Task 22 - Human Factors; D. C. Lookingbill (CONF)
(23) Task 23 - Mechanical Design and Cooling; J. Reardon (CONF)
(24) Task 24 - Reliability; H. J. Klee (CONF)
(25) Task 25 - Grounding, Wiring, Shielding; H. J. Klee (CONF)
(26) Task 26 - Torpedo Detection; W. E. Klund (CONF)
(27) Task 27 - Tracking; H. J. Klee (CONF)
(28) Task 28 - MK 46 Torpedo Jamming; J. Reardon (CONF)
(29) Task 29 - Data Processing Unit; J. Reardon (CONF)
(30) Glossary of Abbreviations

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A 23

S27-20
Task 8573
(NEL J71461)

The Navy Electronics

1. By reference (a) this Laboratory was requested to participate in the AN/SQS-23 Modernization Program (PAIR) by investigating the technical approach including the performance specification and project definition study and by taking the technical responsibility for the design review, the test program and certain aspects of the training. The acceptance letter, reference (b), outlined the schedule and approach proposed by NEL including a concentrated 30-day analysis of the proposed sonar. This is a report of that analysis. At this time several areas of work have not been analyzed to the complete satisfaction of NEL. Results of these studies may still be cause to modify the program at a later date.

2. The ground rules for the analysis were quite simple. The entire analysis was subdivided into approximately 30 tasks and each task was assigned to the individual or group of individuals best qualified in that area. The investigator was asked to examine three things:

a. Is there any major factor which would invalidate the entire concept or require a radically different approach?

b. Are any changes to the specification required in order to insure a more effective (per unit cost) sonar?

c. What additional studies might be required beyond the first 30 days in order to complete all avenues of analysis?

3. The conclusions and supporting discussions associated with each task are attached as enclosures (1) through (29). These conclusions must be consulted to obtain the specification changes. Enclosure (30) is a glossary of abbreviations.

4. While no adverse factors were found during the study which would be cause to halt or radically modify the program, there are three factors which may have a marked influence on the program. The brief discussions of these which follow are supported by the analyses which are given in the enclosed task write ups.

5. The factor which might have the most pronounced influence upon the program is the proposed transducer. Five different transducers are considered: TR-208 (Massa), TR-191 (Harris), TR-197 (Raytheon), TR-177 (Sangamo) and TR-152 (Bendix). None of these has been subjected to a mathematical or empirical analysis which includes all environmental conditions of the PAIR Program. Until such an analysis is made on each candidate transducer, the compatibility of that transducer with the PAIR system is pure conjecture.

6. Preliminary studies indicate that from a bandwidth standpoint only, the TR-208 and the TR-191 might be satisfactory, however the bandwidth is by no

means the only criterion, and it is strongly recommended that empirical tests be arranged at Lake Pend Orielle, Idaho for calibration testing of all candidate transducers. These tests can only be made with complete transducer/amplifier combinations including: entire transducer, mounted receiving array and the TRAM modified power amplifier driver complete with motor-generator power source. If feasible, the dome and baffles should be included. Tests will include all frequency bands, source levels, steering angles, modulation types and duty cycles expected in the PAIR equipment. Results will include source levels, beam patterns, possible amplifier damage and possible transducer damage.

7. The dual bandwidth and high duty cycles imposed by the transmitting modes of the PAIR system constitute the second factor which may have a significant influence on the program. The selection of modes available through the Transmitting Mode Programmer implies changes in hardware as well as operating philosophy in order to provide the essential operating features. The choice of operating modes is based upon the desire to provide search, track and classify functions at a high data rate with a minimum of mutual sonar interference among own ships and a minimum disclosure of information to the enemy. Information disclosure is of two types: One of "super alerting", i.e.: acting in such a way as to announce to the enemy when you have contact on him. The second is disclosing your own ship heading or your range to the enemy. To avoid super-alerting it is necessary to establish a transmission pattern which will provide essential search, track and classify information without making any changes in the transmitting sequences after detection of a possible target.

8. To avoid revealing own ship's heading it is necessary to do two (2) things: first, use ODT transmissions or use RDT transmissions which start at varying relative bearings rather than always starting from the same bearing, and second, avoid any time gaps in RDT transmissions such as an "off interval" for the stern sector. It appears reasonable to instantaneously skip the rotating beam across such a sector.

9. Several techniques are employed to cope with the mutual interference among ships. The use of two (2) separate frequency bands and the use of both upsweep and downsweep FM give considerable freedom to minimize interference. Another feature that appears very attractive is the use of "silent sectors". When operating in the RDT or SLT (Searchlight Transmission) modes, true bearing stabilized silent sectors of 10° will be centered on the one or two adjacent ships so that own ship's major transmitting beam does not blank out consort sonar. Lower level ODT transmissions will provide sonar coverage between ships. The silent sectors will employ the instantaneous sector skip as used for the stern sector to avoid heading disclosure.

10. The following transmitter operating modes are proposed. Typical cases are given here but they are fully described in Enclosure (11) Task 11.

a. Non-alerting, Frequency-Sharing Mode:

(1) Frequency A (Search)

128 Msec, FM, ODT, MCC Pulse; Range 0 - 4 Kyds

followed by:

128 Msec, FM, RDT Pulse; Range 0 - 32, 16 or 8 Kyds

(2) Frequency B (Track/Classify - interlaced with the above sequence)

4, 32 or 128 Msec, ODT, CW Pulse; Range 0 - 8 Kyds

b. Modified Non-alerting, Frequency-Sharing Mode:

This mode is identical to "a" above except that the frequency B transmissions are SLT in lieu of ODT. The 15° searchlight beam is randomly positioned during the normal search operation. However when a contact is made, the operator is allowed to set the SLT bearing on the target a maximum of one sequence in four.

c. Alerting, Frequency-Sharing Mode:

This mode is identical to "b" except that the SLT bearing is under complete operator control.

d. Non-Alerting, Time-Sharing Mode:

Frequency A (or Frequency B) the following pulses are all in sequence:

1 - 128 Msec, ODT, FM, MCC Pulse; Range 0 - 4 Kyd 1 - 128 Msec, RDT, FM, CW Pulse; Range 0 - 32, 16 or 8 Kyd	Search
5 - 32 Msec (or 128 Msec), CW, ODT Pulses; Range 0 - 8 Kyd	T/C
1 - 128 Msec, ODT, FM, MCC Pulse; Range 0 - 4 Kyd 1 - 128 Msec RDT, FM Pulse; Range 0 - 32, 16 or 8 Kyd	Search
10 - 4 Msec, ODT, CW Pulses; Range 0 - 8 Kyd	T/C

e. Modified Non-Alerting, Time-Sharing Mode:

This mode is identical to "d" except that the 5 - 32 ms and 10 - 4 ms transmission are SLT (15° searchlight), the bearing being randomly selected at the beginning of each sequence until a contact is made, at which time the operator can set the bearing once in a sequence of 4.

f. Alerting, Time-Sharing Mode:

This mode is identical to "e" except that the SLT bearing is completely under control of the operator.

g. Alerting, Low Target Density Mode:

This mode is under the control of the operator. The available choices are listed:

(1) For search (used alone until contact)

Transmission	Range Scale Kyd
128 ms, FM, MCC, ODT or	4
128 ms, FM, ODT	4
plus	
128 FM RDT or	32, 16, 8
128 ms CW RDT or	32, 16, 8
32 ms FM RDT	32, 16, 8

(2) For Track/Classify (used after contact)

Transmission	Range Scale Kyd
128 ms CW SLT or	32, 16, 8, 4
32 ms CW SLT or	32, 16, 8, 4
4 ms CW SLT or	32, 16, 8, 4
Burst of 10 - 4 ms CW SLT	32, 16

11. A third factor which might alter the PAIR system somewhat is the display technique. There are many very good arguments for employing a B-scan presentation as the primary search tool in lieu of the PPI display. However it does not appear reasonable to make this judgement at this time based upon NEL or other paper studies. Therefore it is recommended that this portion of the specification be left open (as described by enclosure (8) Task (8) pending a simulation analysis. This simulation, which might be done by Sperry or by NEL, must realistically display data by both display methods for all transmitter operating modes. Probably a conclusion can be drawn from these tests, however it is conceivable that both PPI and B-scan should be provided for on the first two test ships.

12. There are many other facets of this design which can make or break the system when completed and operating at sea. For example, the support rods for the receiving hydrophones, if not made of very low Q material with resonances outside of the frequency band of interest, may introduce intolerable noise level. The conclusions included with each task attached herein will be a major source of information to avoid such pitfalls. Continuing studies in several of these areas by the NEL Project Office will provide a basis for higher confidence in those areas where there is still doubt.

Copy to:
Sperry Gyroscope Co. (Attn:
F. E. Roediger) w/enclosures - 2 cys

Robert D Isaak

R. D. Isaak
By direction

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I. TASK NUMBER: 1

II. TASK TITLE: Passive Arrays

III. INVESTIGATOR(s): C. J. Burbank

IV. CONCLUSIONS

A. Factors Which Might Invalidate The Program

No factors were found that would invalidate the concept.

B. Recommended Changes to Specification

The following changes should be made to the contract specifications:

1. The passive hydrophones must be mounted on vibrationally "dead" rods. (Ref. Paragraph 3.4.2.4 in conclusions of Task Number 6)

2. 3.4.2.9.2 (Impedance Variation). The variation of the free field complex impedance at 20°C and 1 KC between cabled line hydrophones and a hydrophone chosen by the contractor from the first 100 hydrophones to be built, and referred to hereafter as the "Standard Hydrophone", shall be not more than 10%.

3. 3.4.2.9.3 (Plane Perpendicular to the Hydrophone Axis). The free-field receiving patterns in a plane perpendicular to the vertical axis of the line hydrophone when attached to the mounting rod, shall have a variation of not more than ± 1.5 db from circular at any frequency from 1 kc to 6 kc.

4. 3.4.2.9.4 (Plane Containing the Hydrophone Axis). The free-field receiving pattern for the entire line hydrophone in a plane containing the long axis of the hydrophone, when attached to the mounting rod, and over the operating frequency band shall not vary in amplitude more than 15% from the directivity pattern of 8 unshaded elements spaced 6 inches apart. For either the upper or lower half of the hydrophone the free-field

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Enclosure (1)

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Task No. 1

receiving pattern shall not vary in amplitude more than 15% from the directivity pattern of 4 unshaded elements spaced 6 inches apart.

C. Need for Further Investigation

The investigation should continue as new information evolves.

V. DISCUSSION

The directivity, sensitivity, frequency response, and element spacing were checked and found to be in agreement with the PAIR values. Self-noise depends upon the hydrophone mountings. The flow and cavitation noise also contribute to noise background; however the rubber dome is less sensitive to these excitations. USNUSL tests have confirmed these facts.

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I. TASK NUMBER: 2

II. TASK TITLE: Beamforming and Preamps

III. INVESTIGATOR(s): C. J. Burbank and R. J. Vachon

IV. CONCLUSIONS

A. Recommended Changes to the Specification

None

B. Suggested Improvements

None

C. Need for Continued Investigation

A more extensive study could reveal subtle improvements.

V. DISCUSSION

A. Beamforming Techniques

The effect of a change in the velocity of sound in water due to a temperature change from $0^{\circ}C$ to $68^{\circ}C$ will not be observed in the beam pattern or the directivity index of the passive hydrophones as the maximum velocity change will be $\pm 2.8\%$.

The degradation on the output of the WPP due to a signal broadening of 6 microseconds for the worst case will be less than 0.5 db and the signal-to-noise ratio of the output of the PADLOC processor will not be decreased by more than 0.5 db.

B. Calculations of the gain and signal-to-noise ratio of the preamps indicate that they will be satisfactory.

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Enclosure (2)

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Task No. 2

I. TASK NUMBER: 3

II. TASK TITLE: Dome

III. INVESTIGATOR(s): C. J. Burbank

IV. CONCLUSIONS

A. Recommended Changes to the Specifications

None are required for this task since the specifications for the dome appear satisfactory.

B. Suggested Improvements

None

C. Need for Continued Investigation

A continuing review of the dome design parameters should be made at specific intervals.

V. DISCUSSION

The transmissivity of the rubber material has been measured by USNUSL, the shape verified by DTMB, and the strength factors analyzed by Goodrich, all indicating that the design parameters are reasonable and accurate.

I. TASK NUMBER: 4

II. TASK TITLE: PADLOC

III. INVESTIGATOR(s): C. J. Burbank and R. J. Vachon

IV. CONCLUSIONS

A. Recommended Changes to the Specification

None

B. Suggested Improvements

PADLOC II evaluation will give new information which should be used in the PAIR design. The first 5 PAIR units should be made with enough flexibility to allow for variation in integration time (1 to 5 seconds).

C. Need for Continued Study

Work, such as the evaluation of the PADLOC II evaluation, should be continued to produce information affection the operation of the PAIR equipment.

V. DISCUSSION

PADLOC I was tested on the USS GLENNON (DD-840) 25 October - 23 November 1964 and the results compared to results on the same targets obtained on the GLENNON's AN/SQS-23A sonar system. Detection ranges achived by PADLOC were 5 to 10% greater than those achieved by the SQS-23A. No gross design errors were discovered and the equipment was found to be satisfactorily operable.

Serious consideration needs to be given to single frequency noise sources aboard as they will produce a series of parallel lines on the recorder that can occlude real targets.

Task No. 4

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A Human Factors study should be made of the recorder trace to determine any improvements that can be made.

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Task No. 4

I. TASK NUMBER: 5

II. TASK TITLE: Calibration

III. INVESTIGATOR: C. J. Burbank

IV. CONCLUSIONS

A. Recommended Changes to the Specification

None

B. Suggested Improvements

None

C. Need for Continued Investigation

Continued study of in situ transducer calibration is necessary to evolve a satisfactory technique.

V. DISCUSSION

The enclosure presents a transducer calibration technique which has been tried successfully on a TR-177 transducer at Lake Pend Orielle. A single measurement on a TR-208 transducer at LBNSYD indicated complications which require further tests and study before the calibration technique can be used on that model transducer. The TR-208 needs more study to determine the extent to which internal vibration paths effect performance.

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TRANSDUCER CALIBRATION TECHNIQUES
(To be used on AN/SQS-23 or AN/BQS-6 type transducers)

This test was developed to provide a means for determining the condition of a transducer either in the shipyard or installed on the ship. The results of the test program will be used to decided whether the transducer needs repair or not.

The test program consists of three sets of measurements; (1) measure the electrical leakage to ground of each element in the transducer (not new), (2) measure the complex impedance of each element at the operating frequency and determine the resonant frequency. (Only Z was previously measured), (3) measure the sensitivity of a representative sample of the elements of the transducer. (New.)

A brief description of part (3) in the preceding paragraph is given below. The test consists of applying a modified reciprocity technique in the measurement of the sensitivity of the elements. Short pulses will be used in order that the effect of the surroundings can be recognized and eliminated from the measurements.

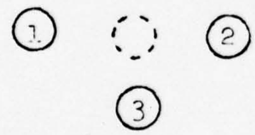

Figure 1

Circles 1 2 and 3 represent elements in three adjacent staves of the transducer. The following measurements are made:

1. Using 3 as the source, measure the open circuit voltages of 1 and 2. The voltages are measured from traces on an oscilloscope.

2. Using 1 as the source, measure the open circuit voltage of 2 for a known current through 1.

Calculate the receiving response of 1 using the following formula:

CONFIDENTIAL

Task No. 5

$$R_{(1)} = \frac{1}{2}\left(V_{(2)} + 2D + V_{(1)} - V_{(2)} - A_{(1)} + J\right)$$

$R_{(1)}$ is the receiving sensitivity of element (1) in db re 1 volt per microbar.

$V_{(2)}$ is the open circuit voltage of (2) measured in 2 above.

D is the directivity correction measured from the elements when they were previously available. (Usually measured at a calibration station).

$V_{(1)} -$

$V_{(2)}$ is the ratio of the output voltages of elements (1) and (2) measured in 1 above.

$A_{(1)}$ is the current in amperes measured in element (1) in 2 above.

J is the reciprocity parameter evaluated for the distance separating (1) and (2) and for the frequency of the test.

$$J = \frac{2d\lambda}{\rho c} \times 10^{-7}$$

It is to be noted that the sensitivity of (2) is obtained at the same time because 1, gave the ratio of the sensitivities of (1) and (2) .

The source sensitivity is obtained from the receiving sensitivity and the reciprocity parameter.

A test of this technique was made on a TR-177 transducer at NELPOCS with the Calibration Station making independent measurements of the elements to give a basis for checking the proposed technique. The measurements were in very good agreement with the calibrations of the elements made by the station.

Additional measurements have been made aboard ships with AN/SQS-23 transducers but there was not opportunity to check the results.

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I. TASK NUMBER: 6

II. TASK TITLE: Quieting - Noise

III. INVESTIGATOR(s): C. J. Burbank, G. M. Coleman

IV. CONCLUSIONS:

A. Recommended Changes tothe Specification

1. Section 3.4.2.4 (3rd and 4th sentences), Rewrite to read: "The line hydrophones (8 elements each) and each hydrophone element shall be vibration isolated such that the transmissibility through the line hydrophone mounting shall be less than 0.1 for the frequency band of 100 cps to 10 kc. The element mounting rods that form the line hydrophones shall be designed toprovide vibration damping with a coefficient of at least 2 percent of critical. The mounting of individual elements shall be such that the transmissibility from rod through mounts to elements is less than 0.1 for the frequency band of 100 cps to 10 kc.

2. Section 3.4.2.5.2 - Add as 4th sentence - "Hydrophone Cable The vibration transmissibility along the cable to any hydrophone element shall be less than that through the element's mechanical mounting system."

3. Section 3.4.5.19 - Add after operator efficiency: "The electronic equipment should be tested for sensitivity to vibration which will increase the background noise in the frequency range of interest for the particular equipment in excess of one-half db. See MIL-STD-167(SHIPS) of 20 December 1954, 1.3 Classification Type I."

B. Suggested Improvements

An additional paragraph or category of specifications should be considered to cover vibration (accelerations) response characteristics of line hydrophones when subjected to a standard vibration level and in

Enclosure (6)

Task No. 6

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a specified direction--in air and in water. Also this category should include vibrations response characteristics of individual hydrophone elements.

Vibration response is usually expressed in db relative to one volt rms per "G" acceleration for each of three mutually perpendicular directions of translational vibrations.

The vibration frequency band should be 100 cps through 10 kc. Excitation by a shaker should be pure tone and one-third octave bands of random noise.

Also the measured response should be by narrow band and one-third octave filters.

The excitation level for testing should be that which is representative for the type ship possibly 0.2 "G" rms.

C. Need for Continued Investigation

1. For both the PADLOC and AN/SQS-23 hydrophone arrays mechanical vibrational response can be an area of seriousness in the sonar self-noise picture. This has been found to be so in the AN/BQQ-2 submarine systems and there seems to be little reason to say that such is not the case for AN/SQS-23 (PAIR).

2. From a waterborne self-noise point of view exploration should be considered in the area of hull near field noise detection. This is possibly a hull design or modification that presumably cannot be considered for the subject contract, but, from a system operation viewpoint this is an area of seriousness and for the future should be weighed carefully and possibly programmed in.

V. DISCUSSION

A. Hydrophone Vibrations Sensitivity

1. From laboratory testing presently underway on NEL Problem L21461 on vibration sensitivity of AN/BQS-6 Transducer Elements for the Submarine 594 self-noise program, it has been found that this is an almost completely overlooked area of the ship's self-noise problem. These elements having sensitivities greater than one volt per "G" acceleration.

2. Also from preliminary self-noise measurements of AN/BQQ-2 system, hydrophone element outputs on submarine (SSN 594) their confirmation that a significant responsiblity for sonar self-noise is attributable to vibration to hydrophones by mountings and hull.

3. The high sensitivity is apparent at hydrophone resonances and correlate "unfavorably" with a number of sonar self-noise "spikes".

4. The suspicion is high that the same similar situation is existent with most shipborne systems and for the subject project early assessment should be made of the significance to the PADLOC System as well as the AN/SQS-23 system.

B. Hydrophone Mounting

To the present none, if any, significance has been placed on possible self-noise controls achieved by vibration mounting techniques for hydrophones. For machinery, etc. considerable advances have been made through the use of decoupling, double mounting and damping.

The project offers a good opportunity to exploit advances in machinery noise control. Presently there is a BUSHIPS (Code 345) Contract with Electric Boat for some study on AN/BQR-7 mounting redesign.

C. Hull Vibration and Near Field Acoustic Radiation

1. This is an area that has enjoyed only little effort from DTMB but to date nothing conclusive has been readied for destroyer class ships. For Minesweepers DTMB has a small project which interests NEL because hull decoupling by air blankets are proposed.

2. The separation of self-noise components, whether structure borne or waterborne has not been assessed nor has the relative significance.

3. The mechanism of vibration energy transmission from or along a hull and hull-water interface to arrays is unknown.

4. Probably the most significant work area that can yield early information is that of vibration-acoustic surveying in domed volumes and on hydrophone mountings. Consequently it is highly recommended that this be done on an installation as soon as possible to give better than guess guidance to self-noise control.

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I. TASK NUMBER: 7

II. TASK TITLE: Interfaces

III. INVESTIGATOR(s): J. Reardon, G. S. Goode

IV. CONCLUSIONS

A. Recommended Changes to the Specification

1. Change Section 3.2.2.3 f of specification to read: "NTDS AN/USQ-20(V) Unit Computer".

B. Suggested Improvements

1. In order to transfer sonar contact information in digital form to the AN/USQ-20 NTDS Unit Computer and receive tactical information in digital form from the NTDS computer implement the following:

a. One (1) computer Input Data Register to hold digital data for transfer to the computer. The register would connect to the 30 input data lines, plus the Interrupt Line, Input Data Request Line and Input Acknowledge Line of the computer input channel.

b. One (1) computer Output Data Register to hold digital data received from the computer. The register would connect to the 30 output data lines, plus the External Function Line, the Output Data Request Line and Output Acknowledge Line of the computer output channel.

c. A keyset assembly containing:

(1) Four (4) keys for designating a tentative track number assigned to the sonar contact by the PAIR operators.

(2) Eight (8) keys for designating the nature of the sonar contact.

(3) One (1) key for inhibiting display of symbols.

(4) Two (2) "Enter" buttons for gating the digital information into the computer Input Data Register.

Enclosure (7)

Task No. 7

2. Information gated into the computer Input Data Register would contain:

a. Tentative Track Number from the keyset - 2 bits

b. Sonar classification or Lost Contact Indication from the keyset - 3 bits

c. Range of sonar contact from Left or Right Track Ball - 11 bits

d. True bearing of sonar contact from Left or Right Track Ball - 11 bits

e. Indication of Active or Passive Sonar Mode - 1 bit

3. Information transferred from the USQ-20 to the Computer Output Data Register would contain:

a. A Local Track Number assigned by the computer - 4 bits

b. A Symbol Code - 4 bits

c. Range - 12 bits

d. True Bearing - 6 bits

The Computer Output Data Word would be stored in one of the PAIR memories. The PAIR Symbol Generator would then interpret the symbol code and display an appropriate symbol on the search CRT at the indicated range and true bearing.

4. The implemented interface with the NTDS computer should be designed to share the computer input/output channel with other equipments. PAIR should have the capability of recognizing and responding to Computer External Function Codes addressed to it while ignoring commands addressed to other equipments sharing the channel.

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C. Need for Continued Investigation

1. After PAIR and ASROC have established a firm track or a target, use the Fire Control position correction operation rather than one of the Enter Buttons to gate digital information into the computer Input Data Register.

2. Increase the number of operator action keys on the keyset assembly from 8 to 16.

3. Provide for two (2) alternate uses of the keyset.

a. Use keyset for communication with the USQ-20 computer as proposed.

b. Use keyset for control of PAIR functions when not necessary to communicate with the NTDS computer, e.g. local entry, classification, display, tracking, etc. of up to four (4) target tracks on the detection display.

V. DISCUSSION

A. Merits of the PAIR/NTDS Interface

Incorporation of a digital interface between PAIR and NTDS would materially enhance, in several ways, the ASW capability of a naval force equipped with both NTDS and PAIR.

1. A semi-automatic keyset for input to the NTDS computer would substantially reduce the time required to report sonar contacts to both the commander of own ship and to the flag ship. Under present procedures contacts are reported aboard own ship over sound powered phones, involving considerable conversation, and to the flag ship by radio. On board the flag ship, time consuming manual plots must then be made of both the reporting ship and the reported contact.

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2. A semi-automatic keyset would increase the accuracy of reporting contacts because verbal reports frequently get garbled in transmission, or are misunderstood by the receiver. Also, human errors are inevitable when constructing manual plots of the reported contacts.

3. Display of symbols from the NTDS computer on the PAIR search display would have the following benefits.

a. Reduce detection time by pointing out a search area where a possible contact might be located, thus limiting the area to be searched. The pointer symbol would indicate to the operator the location of interest.

b. Avoid the misdirected effort of classifying a contact that someone else has already classified. Thus, if a non-submarine symbol were to be presented on the PAIR search display at the range and bearing of a contact under investigation by the PAIR operators, they could transfer their efforts to another contact requiring attention. In like manner, it would be disadvantageous for the PAIR operators to spend time classifying a submarine already known to be friendly. A Submarine Friendly Symbol would quickly inform the operators that the sonar contact is in that category. Another source of wasteful classification effort arises when a surface ship causes an indication on the passive sonar for a considerable period of time before it can be determined on the sonar whether the contact is a surface or a subsurface vessel. If the PAIR operators could be informed at the earliest opportunity by the appearance of a Surface Ship Symbol on the PAIR search CRT that such is the nature of the contact, critical classification time and effort would again be conserved.

c. Another benefit derived from presenting NTDS symbols on the PAIR search display is associated with the NTDS unit computer's ability

to dead reckon several targets when contact has been temporarily lost, or when the sonar's tracking features must be devoted to a higher priority target. The aforesaid symbols would be an efficient means of indicating the computed positions of the dead reckoned targets, and thus assist in regaining contact.

d. Presentation of NTDS symbols would also permit efficient track handover at times when a target was leaving the sector of surveillance assigned to one PAIR/NTDS ship, and entering the sector assigned to another ship similarly equipped.

e. The mutual interference problem would be alleviated by presentation of Surface Ship Symbols on the PAIR search display. The symbols would show to the PAIR operators where other ships in the force were located with respect to own ship. The operators would then inhibit their own sonars from transmitting into sectors occupied by other PAIR equipped ships.

4. Small ship combat data systems of less scope than NTDS, built around 1218 or 1219 computers, are under study. It may prove feasible to retrofit DE's with one of the smaller configurations. In such an eventuality, the proposed PAIR/NTDS interface would also be compatible with the smaller system.

B. Discussion of Pair/NTDS Interface

1. Introduction:

This discussion proposes implementing an interface between AN/SQS-23 (PAIR) and Naval Tactical Data System (NTDS) which affords a modest capability for interchanging tactical information in digital form between the two systems. An effort has been made to limit its scope, in

order to minimize revisions in the proposed PAIR system design and hardware requirements. For example, omitted from this interface proposal are the capabilities for presenting sonar video and audio signals to any portion of NTDS. Also not transmitted to NTDS are the Clue Evaluator settings. Such items of information might be of considerable value, but no provision for their introduction has been embodied here; primarily, to relax the problem of implementing the subject interface. Nevertheless, adoption of this basic interface at this time will provide PAIR with increased versatility and growth potential. That digital information which is exchanged will be augmented by a voice link between the PAIR operators and the ASW Detector/Tracker in NTDS, who supervises the transfer of information.

2. Overview:

Figure 1 is a block diagr m depicting the rudiments of the proposed interface. Digital information is transferred to and from the AN/USQ-20 NTDS Unit Computer by way of two 30-bit registers in PAIR.

The first register labeled CID (Computer Input Data) holds data sent by PAIR to NTDS. This information includes range, true bearing, a tentative track number assigned by the sonar operator(s), and one of two alternative operator actions; i.e., (a) a sonar classification, or (b) a lost contact indication. Finally, the CID register also contains an indication as to whether the source of the data is associated with the active or passive PAIR mode. All of the afore-mentioned information is sent to the USQ-20 computer, which in turn, initiates appropriate indications on the NTDS ASW Detector/Tracker console. If the operator at this console determines that the information should be distribut d throughout the NTDS network, he takes the necessary action at his console. Range and bearing

data inserted in the CID register are obtained by manipulation of one or the other PAIR Track Balls. Tentative Track Number and Operator Action are obtained from a keyset which it is proposed be implemented in PAIR. The Active or Passive Indication is obtained from the system control electronics within PAIR.

The second register labeled COD (Computer Output Data) holds data sent by the USQ-20 to PAIR. This information includes range, true bearing, a local track number assigned by the Unit Computer, and a symbol code. This discussion proposes that PAIR be designed so as to interpret this symbol code, and display a suitable symbol at the indicated range and bearing on whichever PAIR CRT is presenting the search display. Symbol configurations could be chosen to be compatible with the proposed PAIR Symbol Generator.

3. PAIR/NTDS Operation:

Sonar contact information sent by PAIR to NTDS may refer to a new detection, or may concern a target which has been tracked for a period of time and perhaps also been classified. Therefore, either Track Ball may be acquiring the range and bearing data to be inserted into the CID register. Thus, when PAIR assembles a word for transfer to the NTDS Unit Computer, the appropriate Track Ball is manipulated to yield the most refined range and bearing data available. Then, the appropriate Tentative Track Number key and the appropriate Operator Action key are depressed. Finally, the Enter button corresponding to the active Track Ball is depressed, whereupon all of the information is transferred to the CID register to await interrogation by the USQ-20 computer. It is suggested that PAIR have the capability of entering up to four tentative tracks. Suggested Operator

buttons are: Unknown, Submarine Friendly, Non-submarine, Torpedo, Pointer and Lost Co[illegible]ct.

It has been suggested that once PAIR/ASROC have established a firm track on a target, the information intended for NTDS should be gated into the CID register automatically whenever a Fire Control position correction is made rather than upon operation of either of two Enter buttons shown in Figure 1. This would be of valuable assistance, in that it would relieve the tracking operator of additional button pushing at a time when he is apt to be under considerable pressure. It should be incorporated into the interface design.

Information from the USQ-20 computer to PAIR performs the function of advising the PAIR operators of contacts acquired by other NTDS ships, or by other sensors aboard own ship, such as radar. It also serves to designate the boundaries of a sector of surveillance or call attention to some particular area. It is proposed that such information be presented to the PAIR operators by painting appropriate symbols on the search CRT at the ranges and bearings of interest. Once the USQ-20 computer has caused a symbol to appear on the CRT by sending a word to the COD register, it should also have the capability of revising or updating the range and bearing of that symbol. In addition, it should have the capability of changing the symbol to another type. In order to keep books on these changes, and keep PAIR informed, the NTDS Unit Computer assigns a local track number to each symbol, which it includes in the word sent to the COD Register. Finally, the word received by the COD Register contains a symbol code for storage in a PAIR memory and subsequent interpretation by the PAIR Symbol Generator. For a given local track number, the Symbol Generator should

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continue displaying the same symbol at the last received range and bearing until new information on the local track number is received from the NTDS computer, or the track is dropped. It is suggested that provision for display of eight to twelve local tracks be made. It is also suggested that symbols for at least the following meanings be implemented: Surface Ship, Unknown, Submarine Friendly, Submarine, Torpedo, Non-submarine and Pointer. It is also necessary that the USQ-20 be able to instruct PAIR to clear any of the symbols from the search display. This appears to be most simply done by letting one of the symbol codes stand for "Drop Local Track". Or if more convenient, one of the spare bits in the COD word could also be used for this purpose. While the PAIR operators would not have the responsibility for dropping Local Tracks, it does seem advisable that they be provided with a local control allowing them to inhibit display of such symbols on the search CRT.

4. Control of Data Input to Computer when I/O Channel Need Not Be Shared with Other Devices:

Data is transferred from the CID Register to the USQ-20 Computer as 30 parallel bits over 30 data lines. Three control lines are provided for governing the transfer process; namely, an Interrupt Line (IL), an Input Data Request Line (IDRL), and an Input Acknowledge Line (IAL). The step-by-step sequence of events occurring during the input operation is:

a. After the PAIR Track Balls and keyset buttons are properly set up, an Enter button is depressed.

b. The information is gated into the CID Register and allowed to become stable. Proposed structure of the CID word is:

(1) Range: 11 bits; MSB = 32,000 yd, LSB = 31.25 yd.

(2) True Bearing: 11 bits; MSB = 320°, LSB = .3125°

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(3) Tentative Track Number: 2 bits

(4) Operator Action: 3 bits

(5) Active/Passive Indication: 1 bit

(6) Spares: 2 bits

The bit weights chosen for range and true bearing are believed to be compatible with what are available in the PAIR system. In the event that they are not, new weights compatible with available values should be chosen.

c. After the data entered into the CID Register becomes stable, IL is set to "one" and remains a "one" until the USQ-20, at its convenience, samples the CID Register. The word held by the register also remains stable during this time.

d. After sensing the IL and sampling the CID Register contents, the NTDS Unit Computer sets the IAL to "one" for a nominal 15 μs.

e. The CID Register senses the IAL and returns the IL to the "zero" state. Transfer of the word is then complete, and a new word transfer may be initiated. The IDRL is not used in this application. Further particulars regarding AN/USQ-20 input specifications such as voltage levels, impedance levels, timing considerations, etc., are available in reference (b).

5. Control of Data Output From Computer When I/O Channel Need Not be Shared with Other Devices:

Data is transferred from the USQ-20 Computer to the COD Register as 30 parallel bits over 30 data lines. Three control lines are provided for governing the transfer of data: namely, an External Function Line (EFL), an Output Data Request Line (ODRL), and an Output Acknowledge Line (OAL). The step-by-step sequence of events occurring during the output operation is:

a. PAIR automatically sets the ODRL to the "one" state whenever the COD Register is prepared to receive a word from the USQ-20.

b. The USQ-20 senses that the ODRL is a "one", places the word on the 30 data lines, allows the data to settle, and then sets the OAL to the "one" state for a nominal 15 μs. Proposed structure of the resulting COD word is:

(1) Range: 12 bits; MSB = 32,000 yd, LSB = 15.625 yd.

(2) True Bearing: 6 bits; MSB = 240°, LSB = 7.5[1]

(3) Local Track Number: 4 bits

(4) Symbol Code: 4 bits

(5) Spares: 4 bits

The bit weights chosen for range and true bearing are believed to be compatible with what are utilized within the PAIR system. In the event they are not, new values which are compatible should be chosen.

c. PAIR senses the OAL, interprets the word, and drops the ODRL to the "zero" state after completing its interpretation of the COD word.

d. When prepared to receive a new COD word, PAIR again restores the ODRL to the "one" state, and a new word transfer may then be initiated. The EFL is not used in this application. Further particulars regarding AN/USQ-20 output specifications such as voltage levels, impedance levels, timing consideration, etc., are available in reference (b).

6. Sharing A Computer Channel:

The basic PAIR/NTDS interface depicted in Figure 1, and treated in foregoing portions of this discussion has one serious drawback with respect to the AN/USQ-20. It ties up one complete computer Input/Output channel, rendering it unavailable for other uses. Inasmuch as the data rate across the subject interface is expected to be relatively low, this constitutes

inefficient usage of the I/O channel. The situation can be relieved to some extent by arranging for PAIR to share the computer channel with other equipments. This will increase the complexity of the required PAIR hardware to some extent, beyond that shown in Figure 1. Moreover, it will require that those devices sharing the channel with PAIR, conform to certain requirements to be described. Nevertheless, it is recommended that the PAIR/NTDS interface possess this channel sharing capability.

Use is made of all six control lines referred to in paragraphs 4 and 5; namely, IL, IDRL, IAL, EFL, ODRL, and OAL. Care must be taken that only one peripheral device at a time attempts to set those data and request lines which enter the computer. The inactive devices must not load these lines, or otherwise prevent the active device from exercising control over them. Another requirement is that a designated peripheral device be informed when it is to be responsive to those data and acknowledge lines which emerge from the computer. A third requirement is that each of the peripheral equipments sharing the I/O channel be capable of responding to a computer interrogation, even though it doesn't have any meaningful data to send. In order to continue the discussion, the following two definitions will be useful:

a. A peripheral device is said to be "connected" to the input channel when it has control of the IDRL, can place a word on the 30 data lines, and is responsive to the IAL.

b. A peripheral device is said to be "connected" to the output channel when it has control of the ODRL, can sample the 30 data lines, and is responsive to the OAL.

Requirement No. 4 is that all peripheral devices must be capable of interpreting External Function Codes placed on the 30 data lines by the computer event though they are not "connected", whenever the computer sets the EFL to the "one" state for a nominal 15 μsec. Requirement No. 5 is that a peripheral device will automatically "disconnect" itself when it has transferred the requisite number of words called for by the EF code. Rule 6 is that each peripheral device be connected to the IL through one leg of a logical "OR" gate. Thus, at some given instant, one or more of the devices sharing the I/O channel may be responsible for setting the IL to the "one" state.

Whenever the computer is interrupted, it must then interrogate all of the devices sharing the channel, since it doesn't know whether the interrupt was caused by one or several of the equipments. Consequently, all of these devices, including PAIR, are apt to be interrogated at times when they have no meaningful information to supply. Because of this fact, it is suggested that one of the spare bits in the CID word be employed to signify that the CID contents represent new information for the computer. When one of the PAIR Enter buttons gates the information into the CID Register, this bit is set to a "one". Then when the computer samples the CID Register, the bit is reset to "zero" and remains so until new meaningful information is inserted into CID.

The procedure for inputting a word (or words) to the computer is:

a. When any of the devices has data for input to the computer, it sets the IL to a "one" via its leg of the "OR" gate.

b. The computer senses the IL and sends an EF code to the device it wishes to interrogate first, instructing it to "connect" to the input.

c. If that device has its leg of the IL "OR" gate set to "one", it resets it to "zero", "connects" to the input cable, and when it has stable data ready (old or new), sets the IDRL to "one".

d. After sensing the IDRL and sampling the input data at its convenience, the NTDS Unit Computer sets the IAL to "one" for a nominal 15 µsec.

e. The peripheral device senses the IAL and returns the IDRL to the "zero" state.

f. Transfer of a word is complete. If it is not the last word in the message, the peripheral device prepares the next word, and when ready, sets the IDRL to the "one" state. The next word is then transferred as in steps d and e. If it is the last word in the message, the peripheral device automatically disconnects itself from the input, and the computer interrogates the remaining devices in like manner. It is expected PAIR will send only one word messages to the computer.

The procedure for outputting a word (or words) from the computer is:

a. The computer sends an EF code to that device it desires to receive the message, instructing it to prepare.

b. The device senses the EF, "connects" to the output channel, and when it is prepared to receive a word, sets the ODRL to "one".

c. The computer senses the ODRL, places the output word on the 30 data lines, allows it to become stable, and sets the OAL to "one" for a nominal 15 µsec.

d. The peripheral device senses the OAL, samples or interprets the word, and after completing this process, returns the ODRL to "zero".

e. Transfer of the word is complete. If the word is not the last one in the message, the ODRL is set to "one" when the peripheral device is once again prepared to receive the next word, and the next word is transferred as in steps c and d. If it is the final word in the message, the peripheral device automatically "disconnects" itself from the computer output. It is expected that PAIR will receive only one word messages from the computer.

C. <u>Pair/Fire Control Interface</u>

1. The interface between PAIR and the Mark 105, 111 and 114 Fire Control Systems was examined and appears to meet the requirements. The only apparent discrepancy encountered in the specifications was in Sec. 3.4.5.18, Data Conversion Unit (DCU). It appeared that the unit didn't have the capacity for converting qBa and qRa from digital to synchro form. Along with the other quantities, Sperry indicated in a subsequent discussion that qBa and qRa would be converted by synchros attached to the Track Balls and thus not require that the conversion be done via the DCU.

2. There were several questions on the Sperry study not affecting the specifications which caused concern, e.g.

a. In Appendix K which was supposed to explain the interface with the Mark 105, Sperry merely repeated the block diagram for the Mark 111 and presented no information on the Mark 105. However reference to Librascope Document "Simplified Sonar--Fire Control Functional Interface Diagrams AN/SQS-23 Sonar with Mark 105, Mark 111 and Mark 114 FC" indicates the existence of Relay Transmitter MK56 which makes the 105 look like a MK 111

or MK 114 to the sonar. It also makes the SQS-23 look like an SQS-4 to that fire control. Therefore since PAIR is reproducing the SQS-23 outputs, except for stabilization variables which it is handling itself, there appears to be no conflict. The same can be said for output.

b. The Sperry study showed the quantity Bda^1 being converted from digital to synchro form. When questioned about this, Sperry representatives verbally indicated that at one time they planned to use a mechanical azimuth scanner which would require Bda^{ϕ} in syncrho form for stabilization purposes. Now that they have switched to electronic scan, there is no longer a need for the conversion.

c. Pitch and roll information from the MK 19 Gyrocompass and own ship speed from the Electromagnetic Log are 60 cps synchro signals. The Sperry study shows the Data Conversion Unit requires 400 cps synchro signals. Sperry representatives verbally expressed confidence that there are shipboard converters which change 60 cps synchro signals to 400 cps. NAVWEPS OP2667, Vol. I, Part I, "Attack Console Mark 38 Mod 0 Description, Operation, and Maintenance" supports their confidence. It shows Relay Transmitter Mark 45 Mod 0 accomplishing this function. The Mark 19 Gyrocompass and the Electromagnetic Log are standard shipboard equipment.

d. Provision should be made for sending 115v, 400 cps, 1ϕ, 2 wire sonar synchro reference voltage from PAIR to Fire Control. Similarly 115v, 400 cps, 1ϕ, 2-wire fire control synchro reference voltage should be sent from F/C to PAIR. The Sperry study implies that this is to be done but doesn't expressly state it.

D. TRAM/PAIR Interface

This interface is considered in detail in Task Number 16, TRDO Transmitter Portion.

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REFERENCES

a. U[illegible] Ship Integrated Combat System Developmental Model of 28 [illegible] 1964

b. Remington [illegible] Univac: Naval Tactical Data System Technical Note 233A Revised [illegible]/Output Specifications for the CP-642A/USQ-20(V) Unit Computer and Associated Equipment

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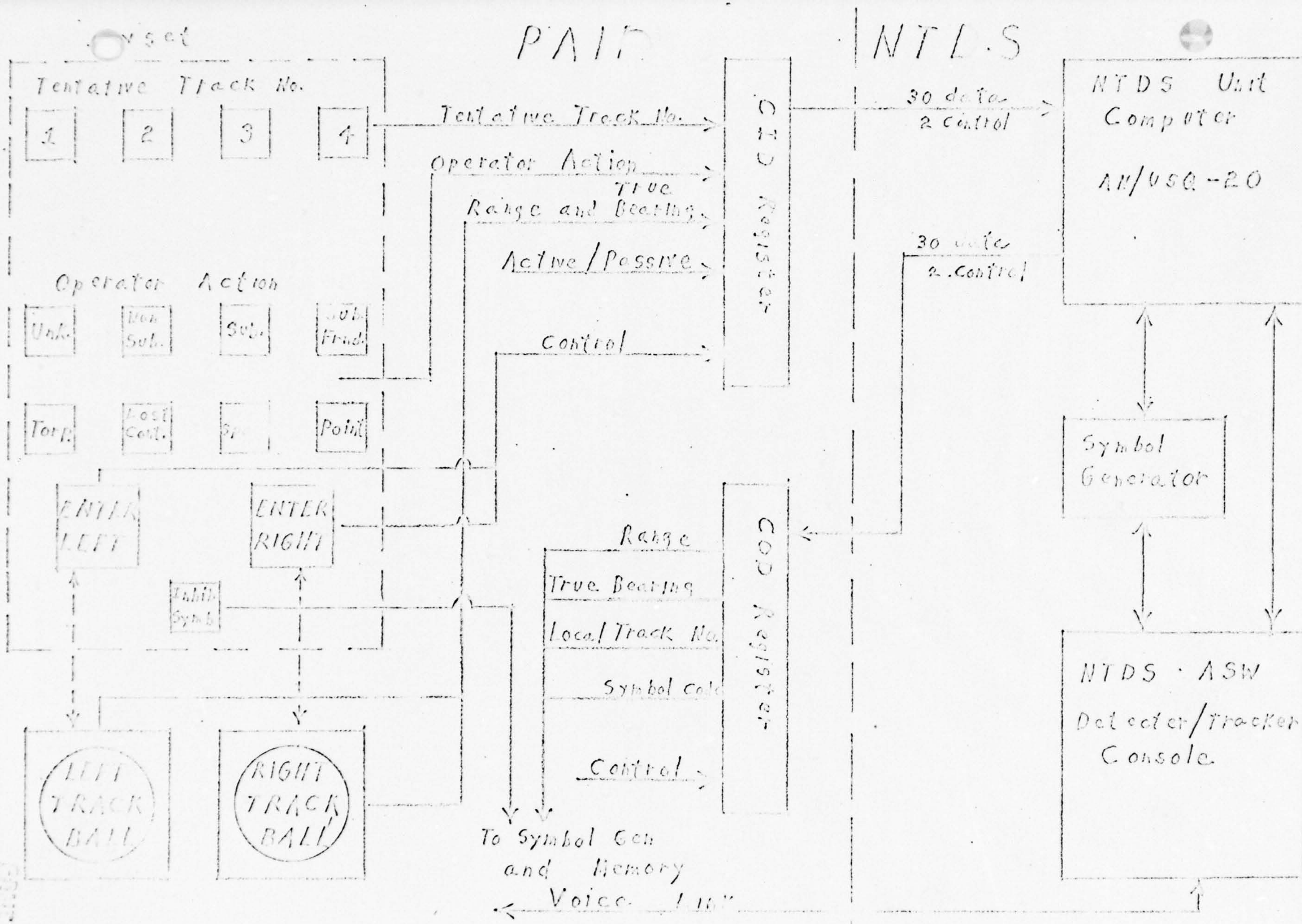

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FIG 1

PAIR/NTDS INTERFACE

Task No. 7

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I. TASK NUMBER: 8

II. TASK TITLE: Displays

III. INVESTIGATOR(s): J. R. Reardon and B. Pennoyer

IV. CONCLUSIONS

A. Recommended Changes to the Specification

1. Section 3.2.1.2.4 - Add. "This console shall consist of two identical display units and an interface unit containing all equipment shared by the display units.

2. Section 3.4.5.12 - Change: "For search operations a PPI-scan shall be provided" to: "For search operations a PPI and/or B-scan shall be provided". Add: "Choice of PPI and/or B-scan for search operations will be decided by ASWSPO after further simulation and analysis". Therefore delete Figure 6.

3. Section 3.4.5.12.1 - Add a new section:

Symbol Generator

A symbol generator shall be provided which is capable of generating at least 16 different symbols. These symbols will be used to indicate a maximum of 12 independent tracks on the detection display. The symbols may be dropped or repositioned in range and bearing by a digital command containing the appropriate track number. One of the 16 symbols shall be an inprocess symbol. The inprocess symbol shall be automatically positioned over the range-bearing bin on the detection display which contains the range-bearing coordinates of the center of the active track display. All symbols shall be displayed at a flicker free rate.

4. Section 3.4.5.13 - Delete: "12-inch" and "with a type P28 phosphor" Choice of CRT size and phosphor will be decided by ASWSPO after further simulation and analysis.

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5. Section 3.4.5.13.1a - Rewrite as follows:

The display shall provide a 360 degree, true bearing, RDT compensated, velocity of sound corrected, flicker free presentation. The data of the 5 most recent pings shall be range binned and bearing clustered about the 48 principle bearings. The data marks shall be spacially separated and visually resovable at 18 inches. A cursor, positioned by the track ball in both range and bearing shall be provided. Symbols representing the passive target in true bearing and own ship's heading shall be written on the outer periphery of the display.

6. Section 3.4.5.13.2 - Add: "The target centered display shall be compensated for own ship's motion in the direction of the target".

7. Section 3.4.5.14.1C - Insert after: "The recorder......... Command to Modes B or C" the following:

"The proper enable commands will be operator selectable as:

a. Left (target range)

b. Middle (Target range minus 1/2 range gate)

c. Right (Target range minus range gate)

d. Commands a, b, c modified at variable linear rate. The value of target range for gating the TRR in Modes B or C can be increased or decreased at a variable linear rate corresponding to rates of 0 ±72 knots selectable by the operator. Continuous compensation for changes due to own ship's motion in the direction of the target will be available to the TRR".

8. Section 3.4.5.6.2d. - Delete this section.

9. Section 3.4.5.13.2 - Change: "For the 4 millisecond pulse, the range gate is constant (650 yards) as a function of range" to: "For the 4 millisecond pulse, the range gate is selectable (650 yards or 1300 yards) and remains constant as a function of range".

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B. Suggested Improvements

1. Section 3.4.5.15 - The figure 8 submitted with the specifications is incomplete and outdated with the latest specifications.

2. Section 3.4.5.17 - Add: There shall be a separate active range and bearing and passive bearing indicator for each cursor.

C. Need for Continued Investigation

1. Section 3.4.5.12

2. Section 3.4.5.13

3. Section 3.4.5.13.1

The type of display, PPI or B-scan, and the display format requires further simulation and analysis before making a decision.

The cathode ray tube size and phosphor require additional testing and analysis before final decision by ASWSPO.

V. DISCUSSION

1. It is technically feasible to make the two display units electrically and mechanically identical. All equipment shared by the two display units such as doppler discriminator electronics, TRR electronics, the clue evaluator, transmit controls, etc. can be combined with the interface unit. This technique will cut production costs and allow greater flexibility in system configuration.

2. Section 3.4.5.12 - It is recommended that the sweep generator be expanded to allow for implementation of both a PPI and a B-scan for the symbolic detection display. The discussion of the search display is covered under 3.4.5.13.1a.

3. Section 3.4.5.12.1 - This is a new section in the specifications. The additions of this section are required to define the scope of the symbol generator. The proposed symbol generator has sufficient flexibility to

perform the original functions of the PAIR sytem (passive target indicator, own ship's heading, and cursor) and yet be flexible enough to work with the NTDS data link. The active target symbol has been modified to an inprocess symbol which will indicate to the search display operator the area under surveillance by the tracking console in both range and bearing. Additional storage for the 12 independent tracks locations is required to enable the operator to display NTDS data and/or to maintain the location and classification of multiple targets. Each of the 12 target symbol words will contain the target type, range, bearing, and track number. This will improve the detection operator's ability to handle multiple target conditions. The complete requirements for the NTDS interface is defined under Task Number 7 which covers NTDS/PAIR Interface.

4. Section 3.4.5.13 - The exact specifications for the tube shape and phosphor type are deleted until the detection display is simulated and analyzed. The shape of the tube may change if the B-scan is adopted.

The preliminary study for PAIR states that the P28 phosphor was chosen as a compromise for display of data with or without the CRT memory. In the original proposal only one memory was available and a long persistance was required for the display without the memory. Now that two CRT memories are included in the system, it appears a new choice of phosphor may be preferred. The P28 phosphor is one of the longest persistance phosphors produced, even longer than the P7 phosphor used in the AN/SQS-23B. Some degree of persistance must be retained for the back-up mode for displaying the analog output of the SDS without memory.

5. Section 3.4.5.13.1a - Based on an evaluation of the proposed PPI detection display, it is recommended that the decision of PPI versus B-scan

for this display be withheld until simulation and analysis of the alternative format is accomplished. We consider the spoked PPI display as proposed unsatisfactory.

It is our understanding that the decision to specify a PPI detection display for PAIR was based to a large extent on a study conducted by Human Factors Research, Inc. The HFR letter report to BUSHIPS dated May 20, 1965 stresses two primary advantages of the PPI over the B-scan. The first of these is operator orientation with the world about own ship. We concur that a PPI is better in this regard but don't consider this is a serious problem on a B-scan. The second advantage listed for the PPI is for analog display of classification information such as axis, shape, and size. We concur that this information is best displayed in the search mode on a PPI. However, the use of the Sum-Difference Scanner for 360° search without memory is considered a backup mode for PAIR because it lacks the signal processing gain, display normalization, and 5 ping history feature of the WPP. It is thus envisioned that it will have a limited use in PAIR for detection.

Classification information will normally be obtained from the Sum-Difference Scanner in the target centered display mode after initial detection on the WPP symbolic display.

After considering the proposed spoked PPI display (See Figure 1) in some detail, we designed a B-scan format for the same size CRT (See Figure 2) for comparison purposes. We will illustrate that this B-scan has a number of significant advantages over the proposed PPI. Included in these advantages are larger and more easily distinguished event mark sizes and spacings, more easily detectable patterns for targets moving in either range or bearing, more effective utilization of the available display area, and better correlation between track ball motion and cursor motion.

The proposed PPI requires the operator to resolve 8 mil (.008") wide lines spaced 8 mils apart. This approaches the minimum resolvable distance of the human eye (5.4 mils at 18" viewing distance) under perfect conditions of illumination and no motion between the operator and the display screen. Recommended display spacing for optimum operator discrimination of adjacent event marks is between 10.8 mils and 16.2 mils. It is important that the operator be able to resolve the position of an event mark in a range bearing bin on the detection display because this position indicates ping number and thus, in a pattern, the direction of motion of a target. The proposed B-scan display corrects this problem with an 11 mil line width and 11 mil spacing. These larger event marks will also improve the operator's discrimination of intensity level, an indication of signal strength.

Patterns of targets traveling in bearing are difficult to recognize on the proposed PPI because the operator must correlate event marks in adjacent beams which vary in separation from 80 mils at the center of the display to 655 mils at the periphery. On the proposed B-scan this separation is a constant 172 mils, yielding easier recognition of these target patterns.

Utilization of the display area on the proposed 10" circular PPI screen is very poor (19.5%). The proposed B-scan utilizes 62.8% of the rectangular 8.4" x 6" area selected. The larger range dimension on the proposed B-scan (6" vs. 4.4" for the PPI) provides a longer event mark and has the added advantage of easier positioning of the cursor in range for handoff to the TCD. This is particularly critical in the single ping mode where the detection display has 240 range bins. This range dimension could be further increased without an objectionably large CRT by going to a rectangular tube screen.

Optimum correspondence between track ball motion and cursor motion cannot be provided on a PPI for both random positioning and audio search, i.e., if x-y motion of the track ball yields ρ-θ motion of the cursor, random positioning of the cursor is very awkward. On the other hand, if x-y motion of the track ball yields x-y motion of the cursor, beam-to-beam audio search must be accomplished by an awkward circular movement of the track ball. The case of ρ -θ motion of the cursor is further objectionable because the same track ball is used to position a cursor on the passive detection display which necessarily has x-y motion. These problems do not occur in the case of the B-scan, where both random positioning and audio search are accomplished with optimum correspondence of x-y motion of both the track ball and the cursor.

A summary of the pertinent parameters of the proposed PPI and B-scans are shown below:

	PPI Display	B-scan Display
Event Size	8 x 90 mils	11 x 110 mils
Event Spacing	8 mils	11 mils
Space between bearing bins*	80 to 655 mils	172 mils
Display Density	19.5%	62.8%
Display Size	10 inch circle	8.4 x 6 inches
Display Area	77.3 sq. in.	50.4 sq. inches

*This space is measured from identical ping positions in adjacent range-bearing bins.

From a hardware viewpoint, a B-scan detection display would be cheaper to implement than the proposed PPI which requires a radial scan with incremental displacements proportional to bearing.

Based on the fact that the proposed PPI symbolic detection display is not considered satisfactory and that valid arguments can be presented for

the choice of a B-scan symbolic detection display, we strongly recommend that:

1. Simulation of both a PPI and a B-scan digital symbolic display be performed to determine acceptable display formats. This simulation should include realistic target motions and the effects of pitch and roll errors on this unstabilized detection display.

2. Both the PPI and B-scan detection displays be implemented for the two PAIR SYSTEMS schedule for sea trials.

Informal discussions with Sperry personnel indicate that neither of these items would delay the scheduled delivery of the PAIR equipment. Further the implementation of both the PPI and B-scan detection displays for sea trials won't require any extensive modification to the proposed sweep circuitry.

6. Section 3.4.5.13.2

It is necessary to compensate the TCD for own ship's motion in the direction of the target. If the TCD is not compensated, the relative range rate may reach 70 knots. It can be shown that with a relative range rate greater than 30 knots the probability of maintaining the target on the display after one ping is very small.

7. Section 3.4.14.1C

The TRR range gate (800 to 1600) yards) provides insufficient track history for classification of high range rate or long range targets, unless repositioned. Repositioning by the operator introduces edge and highlight distortion due to unequal incremental corrections. An increase in range gate size is detremental to highlight and echo length clues.

.The TRR writing density (lines/inch) is fixed at a predetermined value. The rate at which the lines are printed is determined by the selected range scale while physical spacing between lines remains constant. The slope of the range versus time points, indicating range rate of the target, will therefore change for each range scale.

The limitations mentioned above will be alleviated by providing the operator with the capabilities of positioning the initial target returns at the center or either extreme edge of the range gate and of gating the TRR in range at a variable linear rate. When a target is initially detected and transferred to the track console the ideal position of the target in the TRR range gate would be at the center. This would allow an indication of opening or closing range in several pings. Once this has been determined the operator should position the target return at either extreme edge of the range gate, depending on opening or closing range rate. The capability of modifying

the range, at which the TRR is gated, at a variable linear rate will allow the operator to offset the TRR gate corresponding to the change in range due to target's motion. Manipulation of the variable linear rate to obtain vertical alignment of the TRR traces would indicate a compensation value equal to target range rate. The value of the compensation would be a matter of operator judgement with small modifications as the problem progresses.

The change to section 3.4.5.14.1C will provide a continuous history of target traces without destroying edge and highlight alignment. Target range rate indication will no longer be distorted due to changes in range scales.

8. Section 3.4.5.6.2d. Recommended changes to section 3.4.5.14.1C eliminates the requirement of a range-rate marker and the need for this section.

9. Section 3.4.5.13.2 - A worst case statistical analysis indicates that the 650 yard range gate specified in the 4 ms pulse mode is not large enough to maintain moderate speed targets on the TCD when in the 16 kyd search and track range scales. Normal distributions of target position errors were assumed with zero mean and with standard deviations of range errors of 1% and of bearing errors of 0.5°. Under these conditions we could not maintain with 90% confidence a 5 knot target on the TCD beyond 12 kyds; a 10 knot target beyond 8 kyds; or a 15 knot target beyond 4 kyds. With the same assumptions, on the 8 kyd search and track range scales we could not maintain a 15 knot target beyond 7.5 kyds or a 20 knot target beyond 5.0 kyds.

It is therefore recommended that a 1300 yard range gate be available on the TCD for the 4 ms pulse mode. When aided tracking is allowing the operator to hold the target near the center of the TCD, he can then select

the 650 yard range gate on the 4 ms mode to obtain improved axis, shape, and size classification information on the TCD (Details of this analysis will be available in a technical memorandum at a later date).

Another possibility under investigation is to use a 15-degree bearing sector on the TCD and to reorganize the CRT memory to utilize the resulting excess bearing cells as additional range cells. This would allow use of a 1300 yard range gate size on all pulse length modes without degrading the display of axis, shape, and size clues. In this case, it would even be feasible to increase this range gate size to 1600 yards to match the TRR gate size. The 1600 yard gate size would require increasing the sampling interval of the Sum Difference Scanner to 4 ms when the 4 ms pulse length mode. This sampling interval is acceptable.

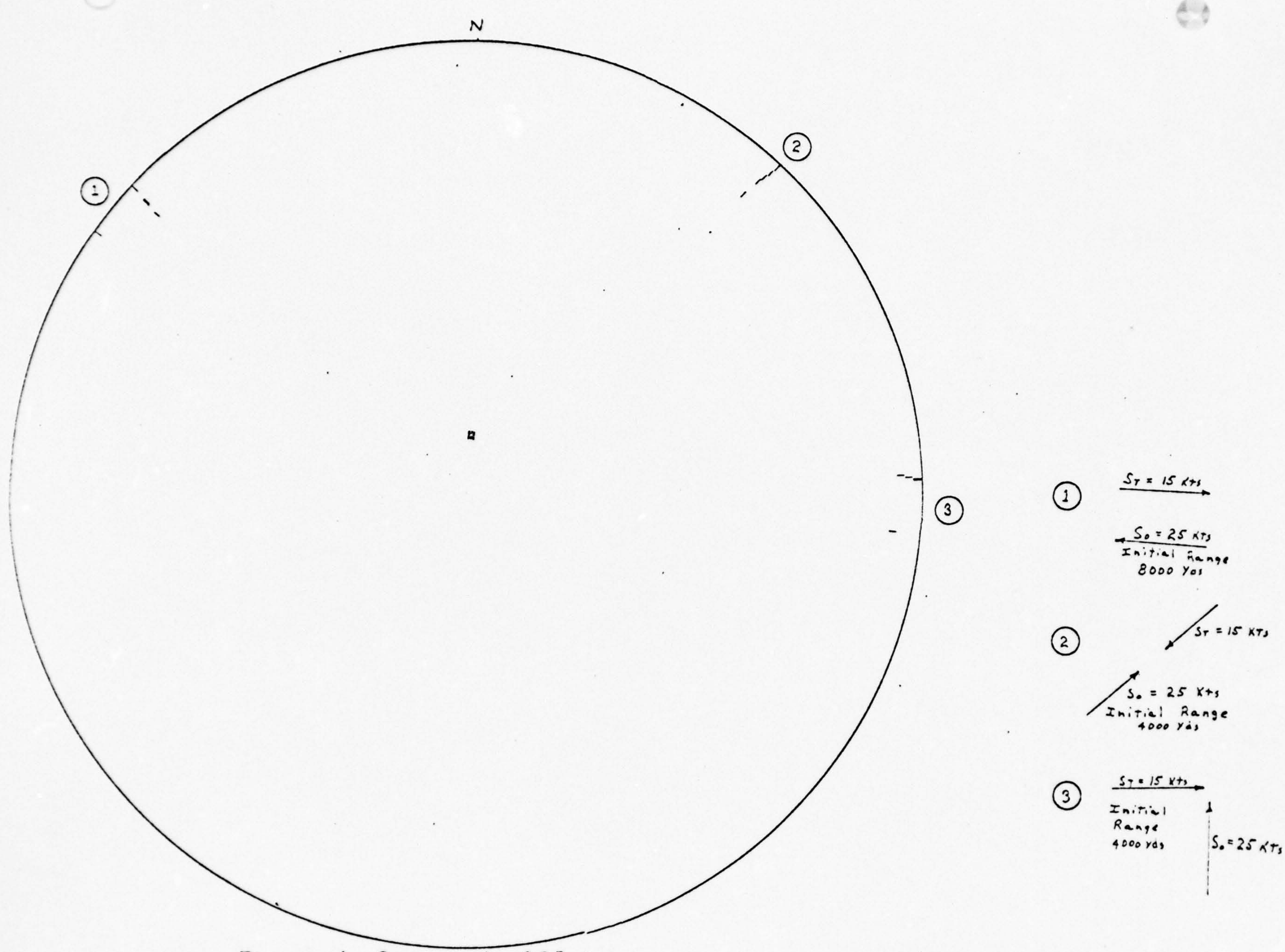

Figure 1 Proposed PPI Display
Task No. 8

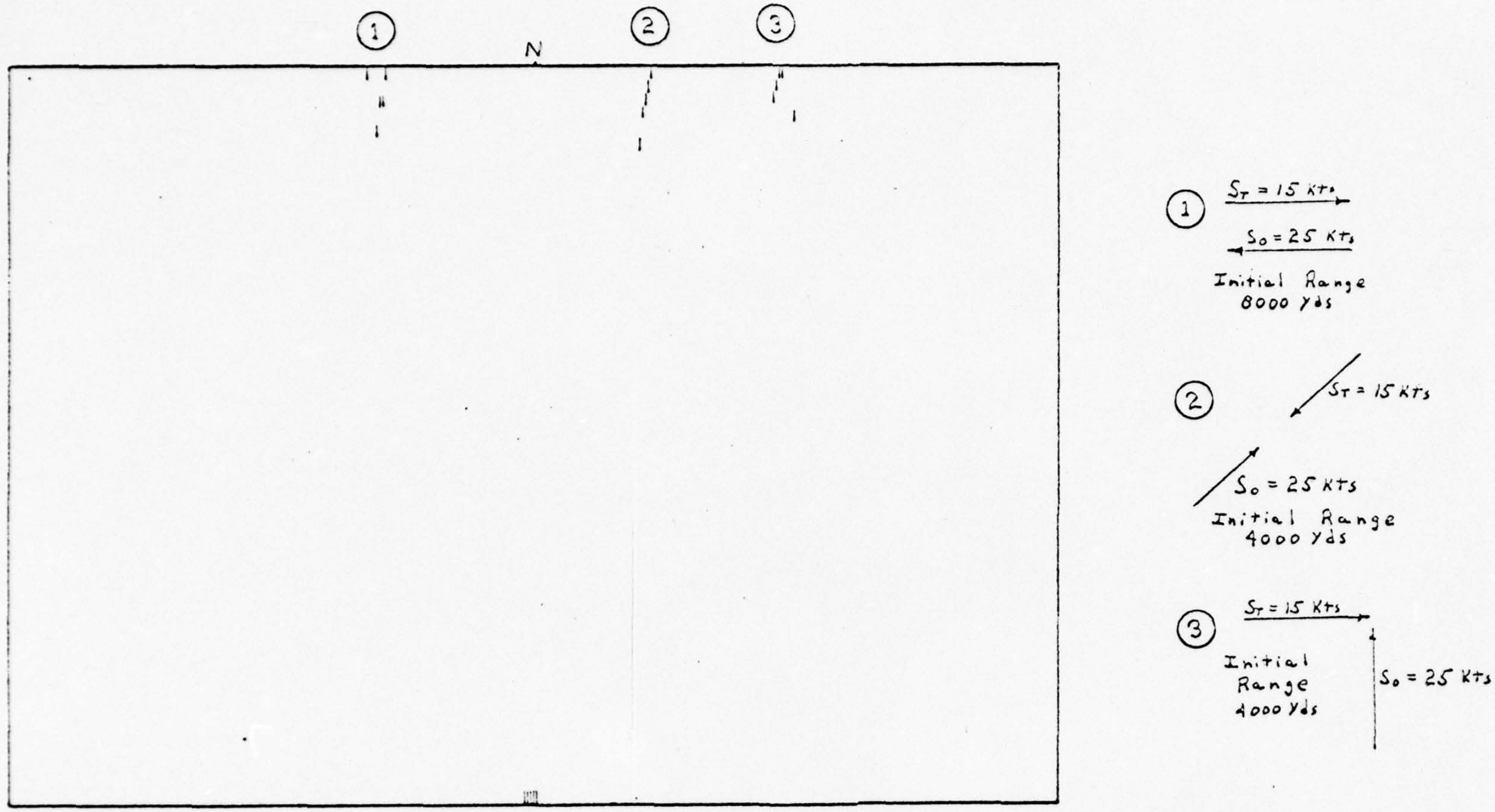

Figure 2 Proposed B-Scan Display

Task No. 8

I. TASK NUMBER: 9

II. TASK TITLE: Simulation

III. INVESTIGATOR: J. Reardon

IV. CONCLUSIONS

A. Recommended Changes to the Specification

See Task Number 8 - Display and Task Number 15 - Signal Processing

B. Suggested Improvements

See Task Number 8 - Display

C. Need For Continued Investigation

See Task Number 8 - Display

V. DISCUSSION

Considerable discussion of our recommendations for the simulation of the detection display before a decision is made on format and type of scan is included in Task Number 8 - Display.

A number of changes have been recommended in the performance requirements specifications (see Task Number 15 - Signal Processing) to facilitate our ability to simulate and measure the required signals and noise for testing conformance to those specifications.

I. TASK NUMBER: 10

II. TASK TITLE: Microcircuits

III. INVESTIGATOR(s): J. Reardon, R. Potterf, Dr. Kerrigan, J. Poulson

IV. CONCLUSIONS

A. Recommended Changes to Specification

None

B. Suggested Improvements

None

C. Need for Continued Investigation

1. Follow PADLOC III tests closely as regards to the use of a sliding voltage power supply and low noise preamplifiers.

2. Watch for any increased digital circuit speed requirements in PAIR.

V. DISCUSSION

The use of sliding voltage power supplies which sense the temperature near the digital microcircuits and adjust the voltage output of the associated power supplies accordingly is not a proven technique. Its purpose is to allow the use of cheaper mid-temperature range microcircuits over the full MIL temperature range of $-55^{\circ}C$ to $+125^{\circ}C$. Questions which immediately come to mind are where are the temperature sensors placed to insure proper adjustment of all circuits associated with a given power supply? Do all types of digital circuits that may be common to a given power supply have the same Δ voltage versus Δ temperature characteristics? What problems arise when a signal is passed between circuits in two power supply groups? etc. Since the microcircuit version of PADLOC uses this technique and is due for testing shortly, it is our recommendation that this feature be thoroughly evaluated in those tests.

Enclosure (10)

Task No. 10

The specifications of .08 microvolts self noise in 400 cps band and 100 db dynamic range for the PAIR preamplifiers are certainly difficult to achieve, particularly in a system configuration as opposed to a bench test of a single preamplifier.

Since RTL microcircuits are one of the lower speed configurations available, any design changes in PAIR which require clock frequencies in the range of 4 mc should be closely studied.

Other items considered in a brief analysis were the proposed flat pack mounting and soldering techniques, grounding and shielding techniques, numbers and types of microcircuits per card, and circuit specifications.

No significant problems are anticipated in these areas if good circuit and systems engineering techniques are employed in PAIR.

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I. TASK NUMBER: 11

II. TASK TITLE: Operating Modes

III. INVESTIGATOR(s): W. E. Klund (with inputs from R. Eady and L. Mulcahy. Prepared by Dr. B. Brown, TRACOR)

IV. CONCLUSIONS:

A. Recommended Changes to the Specifications

1. Add: Section 3.3.3 (d) "Transmit sector blanking (3.3.3.1) to remove likelihood of transmitting directly toward another SQS-23 (PAIR) ship".

2. Add: Section 3.3.3.1 - "Circuitry shall be provided which will inhibit the RDT and SLT mode transmitted signals in any two selected 10-degree sectors. These sectors shall be true bearing stabilized, and shall be capable of being independently positioned and actuated, when needed. In the RDT mode, the blanked sectors shall be stepped over without time delay".

3. Replace Section 3.4.4.1 to read: "Transmitter Control Unit - The transmitter control unit shall provide:

(a) transmitter electronic scan

(b) sector control

(c) transmitter control to prevent exceeding the allowable duty cycle.

(d) transmitting mode programming through the use of a Transmitting Mode Programmer".

4. Add: "Section 3.4.4.4 Transmitting Mode Programmer

The Transmitting Mode Programmer shall automatically transmit a sequence of search and track/classify pulses and select the proper processor for processing and display of information. Normally the operator selects with

a single knob one of a number of programmed modes. Each of these modes shall be capable of being modified for different environmental conditions."

5. Add: "Section 3.4.4.4.1 - The following Transmitting Mode Programs shall be selectable by the operator:

(a) Mode I(a): Non-alerting, Frequency-shared Mode

(b) Mode I(b): Non-alerting, Time-shared Mode

(c) Mode II(a): Modified Non-alerting, Frequency-shared Mode

(d) Mode II(b): Modified Non-alerting, Time-shared Mode

(e) Mode III(a): Alerting, Frequency-shared Mode, Operator Controlled SLT Bearing

(f) Mode III(b): Alerting, Time-shared Mode, Operator Controlled SLT Bearing

(g) Mode III(c): Alerting, Low Target Density"

6. Add: "Section 3.4.4.4.1.1 - The Transmitting Mode Programmer shall be capable of selecting among the following alternatives for Mode 1(a)

(a) Search Frequency: 4.5 kc/s or 5.5 kc/s. The T/C frequency shall automatically be the alternate frequency.

(b) Search Range Scale: 32 kyd, 16 kyd, or 8 kyd.

(c) Track/Classify Range Scale: Any r nge scale less than or equal to the search range scale.

(d) The Transmitted Pulse Form, Paulse 1: 128 ms FM ODT, 32 ms FM ODT, or 128 ms CW ODT; MCC or not. This transmission is observed on the inner 4 kyd of the PPI binned display.

(e) The Transmitted Pulse Form, Pulse 2: 128 ms FM RDT or 32 ms FM RDT. A 128 ms CW RDT shall be capable of being programmed once in each six FM transmissions.

(f) The Transmitted Pulse Form, Pulse 3(a):

128 ms CW ODT, 32 ms CW ODT, or 4 ms OW ODT. Pulse 3(a) is normally alternated with pulse 3(b). Pulse 3(b) is a 4 ms CW ODT.

(g) An alternative burst mode using 10 3(b) pulses shall be programmable at spacing compatible with the 800 yd GR gate and the GR recycle time. When this mode is programmed the 3(a) and 3(b) pulses shall not be alternated, but six 3(a) pulses shall be transmitted for each burst transmission. This alternative shall be programmable only on the 32 kyd and 16 kyd search scales.

(h) A normal mode sequence shall consist of the transmissions of a number of pulses, for example: 1, 2, 3a, 3b, 3a, 1, 2, 3b, 3a, 3b, etc. The 3(a) pulses are automatically prevented from reaching the graphic recorder. In the burst mode the sequence 1, 2, 3(a), 3(a), 3(a), shall be repeated five times, the next sequence shall be 1, 2, 10 - 3(b). In each case pulse 2 and 3(a) or 3(b) are transmitted in rapid sequence on different frequencies.

(i) The gating and programming of the displays to be used with the programmed modes shall be controlled by the transmitting mode programmer."

7. Add: "Section 3.4.4.4.1.2 - The Transmitting Mode Programmer shall be capable of selecting for Mode II(a) all of the alternatives listed in 3.4.4.4.1.1. This mode shall utilize SLT (searchlight transmissions) rather than ODT for the T/C pulses (3a and 3b). The SLT shall have a 15°

beamwidth whose bearing shall be randomly changed at periodic intervals having a duration compatible with the range scales in use. The operator shall be capable of forcing the next bearing selected to be that indicated by the search cursor for not more than one in four such intervals. The steered beam receiver shall be slaved to the SLT bearing."

8. Add: "Section 3.4.4.4.1.3 - The Transmitting Mode Programmer shall be capable of selecting for Mode III(a) all of the alternatives listed in 3.4.4.4.1.1. This mode shall utilize SLT with the bearing under operator control. The steered beam receiver shall remain slaved to the SLT bearing."

9. Add: "Section 3.4.4.4.1.4 - Provision shall be made for silent sectors in the RDT. The baffle sector and two steerable 10° sectors shall be silent. The RDT shall jump through these sectors with no time lag. Sonar and displayed data shall be corrected for these discontinuities in timing."

10. Add: "Section 3.4.4.4.1.5 - Provision shall be made to start the RDT at 8 different, equally-spaced bearings with a position stepper which automatically steps the starting bearing between successive RDT search intervals."

11. Add: "Section 3.4.4.4.1.6 - The Transmitting Mode Programmer shall be capable of selecting for mode I(b) all of the alternatives listed under 3.4.4.4.1.1. The following additional alternatives shall also be available: The number of 3(a) pulses in Cycle 1, the number of 3(b) pulses in cycle 2 or the choice of a burst mode in cycle 2. All the transmissions shall be automatically on the same selected frequency, however, in contrast to 3.4.4.4.1.1.(a)."

12. Add: "Section 3.4.4.4.1.7 - The transmitting mode programmer shall be capable of selecting for modes II(b) and III(b) all of the alternatives available in 3.4.4.4.1.6. For Mode II(b) an SLT transmission shall be substituted for the ODT T/C transmissions. This transmission shall have all the characteristics described in 3.4.4.4.1.2. The steered beam receiver shall be slaved to the SLT bearing. For Mode III(b) the operator shall have complete control of the SLT T/C tra[illegible] in 3.4.4.4.1.3."

13. Add: "Section 3.4.4.4.1.8 - For Mode III([illegible] transmitting mode programmer shall be capable of selecting all of the alternatives available in 3.4.4.4.1.1, 3.4.4.4.1.2, 3.4.4.4.1.3, 3.4.4.4.1.4, 3.4.4.4.1.5, 3.4.4.4.1.6 and 3.4.4.4.1.8. This mode shall be a manual mode in which the operator normally utilizes pulses 1 and 2 for detection and then switches to pulses 3(a) and 3(b) as necessary for classification and tracking."

14. Section 3.4.5.1.3 - Modulation, add: "a pair of" between "with" and "modulators".

15. Section 3.4.5.1.4 - Filtering, change line 2: "preformed beam" to "modulator".

B. Suggested Improvements

None

C. Topics for Further Investigation

1. The details of the mode sequences specified in IV.A should be tested against particular operational situations. Estimates of performance with these and other combinations of pulse forms with single ship, two ships, four ships, etc., and for several water conditions should be studied in detail. After these studies are completed some restrictions in the choices available on the programmer may be suggested.

2. The option of 128 ms CW pulse length for the doppler discrimination and tracking should be investigated in detail for several operational and water conditions. This is mentioned in the signal processing task (Number 15). The study recommended there will provide the signal processor inputs for this study.

3. Mode sequences specified in IV.A should be examined in the light of utilizing the receiving time more efficiently even though receiving intervals may sometimes be blanked by transmissions. An increase in data rate is possible at the expense of an occasional lost echo due to receiver blanking by the transmitter. After these studies, changes in the mode sequences may be suggested.

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V. DISCUSSION: (Choice of Operating Modes)

A. INTRODUCTION

The choice of operating modes is to be based upon performance requirements in several situations and is of course restricted by the results which can be obtained with a given pulse form. The restrictions to be imposed can be presented in three statements:

1. The pulse forms suitable for search (S) do not provide the necessary track (T) and classification (C) information.

2. Transmission sequences which minimize target alerting are required.

3. Transmissions which minimize mutual interference between ships are required.

The discussion which follows begins with a list of the available modes. These modes may be chosen in the proper sequence to accomplish the required functions when no restrictions such as multiship operation or non-alerting operation are imposed.

When additional ships equipped with the AN/SQS-23 (PAIR) come on the scene, certain restrictions are imposed concerning the permissible transmissions. The choice is again narrowed when operation must be the "non-alerting" variety. Specific modes designed to provide S and T/C transmissions while providing "non-alerting" features and reduced mutual interference are described.

B. THE AVAILABLE MODES

The operational modes available to the operator of the AN/SQS-23 (PAIR) have been provided to furnish efficient search, track and classification information. The ODT or RDT FM will be available in conjunction with the wave period processor (WPP) for search. The track/classify (T/C) operation will

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be accomplished with 128 or 32 ms CW SLT in conjunction with the sum and difference scanner or the Doppler Discriminator and with 4 ms CW SLT in conjunction with the graphic recorder.

In addition the passive modes provide the search function with the PADLOC array and the clipper cross-correlator and the passive track function also utilizing cross-correlators.

The available operating modes are listed in Tables I and II.

TABLE I

AVAILABLE ACTIVE OPERATING MODES

Function	Transmission	Processor	Display
S	128 ms FM ODT	WPP	CRT
S	128 ms FM RDT	WPP	CRT
S	32 ms FM ODT	WPP	CRT
S	32 ms FM RDT	WPP	CRT
S	128 ms CW RDT	WPP	CRT
T/C	128 ms CW ODT	SBR, SDS, DD	CRT
T/C	32 ms CW ODT	SBR, SDS, DD	CRT, GR
T/C	4 ms CW ODT	SBR, SDS	CRT, GR
T/C	128 ms CW SLT	SBR, SDS, DD	CRT
T/C	32 ms CW SLT	SBR, SDS, DD	CRT, GR
T/C	4 ms CW SLT	SBR, SDS	CRT, GR

TABLE II

AVAILABLE PASSIVE OPERATING MODES

Beams	Bandwidth	Processor	Display
Search 24	1.0 - 2.5 kc/s	Correlator	GR
Track 6	1.0 - 1.8 kc/s	Correlator	CRT

A simplified block diagram of the active and passive equipment is shown in Figure 1. Two CRT displays and two graphic recorder (GR) displays are

available. This does not in general provide redundancy as claimed in the Sperry Report because when the active and passive search and track are being simultaneously attempted, both graphic recorders and both CRT displays are being used.

In general, the passive and active systems will be employed simultaneously no matter what operational restrictions are imposed in order to maintain a high detection probability under as many conditions as possible. It can also be concluded that the search operation will nearly always be in progress so that one CRT and one GR will always be in use. The active transmission will generally be the 128 ms 400 c/s FM sweep. The upsweep or the downsweep may be chosen, and transmissions may be made centered either at $f_1 = 4.5$ kc/s or at $f_2 = 5.5$ kc/s. A maximum of four ships could use these search modes while keeping mutual interference to a minimum.

At the time a contact is made by one of the ships either passive or active track may be initiated. If search is continued while tracking is in progress, the other GR and the other CRT will have to be used, and the CRT will be required simultaneously on two of the active functions, namely, search and track. Clearly the passive track, active track and active search, all requiring CRT display, cannot be carried out simultaneously without display sharing.

The type of operation described above will be adequate only when the single targets are encountered or when detection followed by target alerting (switching to a SLT T/C mode) is permissible in analyzing the contact. It will not be sufficient as the target density increases and search for new targets must be continued while tracking and classification of a previous contact is underway. This conclusion can be reached by considering the

amount of time necessary to obtain tracking and classification as a function of target range. Table III provides a time table for the 32 kyd range. On the 16 kyd range scale, these times may be halved. The table shows that a 5-ping search history requires 4.1 minutes, a 5-ping track/classify history requires 4.1 minutes, and a 10-ping highlight history requires 8.2 minutes. If these functions are carried out in turn on a 32 kyd scale, a total of 16.4 minutes will be required. Time sharing of these functions in this way extends the time between first contact and possible weapon launch.

TABLE III

TIMES REQUIRED TO OBTAIN SEARCH AND TRACK/CLASSIFY INFORMATION

Function	Range Scale (kyd)	No. of Pings	Min. Time (Min.)
Search (128 ms FM)	32	1	0.8
		5	4.1
Track/Classify (128 ms CW)	32	5	4.1
Classify (4 ms CW)	32	10	8.2
TOTAL			16.4 Min.

An alternate procedure is to change transmission repetition rate on the T/C pulses and resolve the possible range ambiguity with the search information. A third procedure is to provide for simultaneous T/C and S transmissions on a frequency-sharing basis. In single-ship operation this provision provides track-while-search or classify-while-search capability without own-ship interference. The cost of this feature is increased mutual interference in multi-ship operation if the track/classify frequencies of one ship are chosen to be the search transmission frequency of another.

C. BASIS FOR CHOOSING MODES

A number of operational goals are involved in choosing the operational modes. Among the most important are the following:

1. Deny the target knowledge that he has been detected. This goal will be accomplished by using "Non-alert" transmission modes.

2. Deny the target knowledge of sonar ship heading.

3. Reduce mutual interference between ships working in the same area.

There are no universal modes which accomplish all of these goals simultaneously. This being the case, it is necessary to provide a number of transmission modes, so that the one providing the best performance under the prevailing operation conditions can be selected.

The modes which have been chosen have been labeled as follows:

I. Non-alert Modes
   (a) Frequency shared
   (b) Time shared

II. Modified Non-Alert Modes
   (a) Frequency Shared, Pseudorandom SLT Bearing
   (b) Time shared, Pseudorandom SLT bearing

III. Alerting Modes
   (a) Frequency shared, Operator Controlled SLT bearing
   (b) Time shared, Operator Controlled SLT bearing
   (c) Low Target Density Manual

It is recommended that the console be equipped with a knob which selects these modes.

D. DISCUSSION OF THE MODES

I. The Non-Alert Modes

The non-alert mode is designed to deny to the target knowledge that he has been detected. It consists of a sequence of different transmissions which are transmitted to provide a continuous opportunity for search, track, and classification. A form of the mode referred to as the frequency-shared form is illustrated in Figure 2(a). Search transmissions are made on one frequency, track/classify transmissions are made on a second frequency.

The characteristics of the transmission, for the 32 kyd search, 8 kyd track/classify sequence are listed in order of use.

Pulse No.	Function	Type	Range Scale	Frequency	Number per Repetitive Sequence	Processor/ Display
1	S	128 (or 32) ms FM ODT MCC (or not)	4	f_1	2	WPP/CRT_1
2	S	128 (or 32) ms FM RDT	32	f_1	2	WPP/CRT_1
3(a)	T/C	32 (or 128 or 4) ms CW ODT	8	f_2	3	DD, SDS/ GR_1, CRT_2
3(b)	T/C	4 ms CW ODT	8	f_2	3	SBR/GR_1

The No. 1 pulse (128 or 32 ms FM ODT MCC or not) is transmitted and the return is observed on the first 4 kyd of the PPI, binned display. The No. 2 pulse (128 or 32 ms FM RDT) is transmitted and the return is observed on the PPI, binned display in the range interval from 4 kyd to 32 kyd. These two transmissions are made on frequency f_1 = 4.5 kc/s* (or f_2 = 5.5 kc/s). The No. 3(a) (or No. 3(b)) pulse will be transmitted next, immediately after the No. 2 pulse. The 3(a) and 3(b) pulses are alternated at regular intervals, at a rate determined by the T/C range scale (8 kyd).

*This choice is arbitrary if one ship operation is taking place. If several ships are present which must share the available bandwidth, some will choose f_1 and some f_2.

In general there will be several of the No. 3 pulses per RDT transmission. For example, the R(T/C) - 8 kyd mode shown in Figure 2a, provides a T/C transmission approximately every 20 seconds and three No. 3 transmissions are made for each No. 1 or each No. 2 transmission. The No. 3(a) pulses are specifically for tracking and doppler discrimination. The No. 3(b) pulses are for highlight determination. Only the 4 ms pulse is to be gated to the graphic recorder.

In the example mode being described (32-8) the complete set of transmissions per sequence is shown in Table IV, pulses 3(a) and 3(b) being alternated.

TABLE IV

COMPLETE 32 KYD - 8 KYD MODE I(a) SEQUENCE
(Non-Alerting, Frequency-Shared Mode)

Detection Cycle	Transmissions
1	1-No 1 1-No 2 1-No 3(a) 1-No 3(b) 1-No. 3(a)
2	1-No 1 1-No 2 1-No 3(b) 1-No 3(a) 1-No 3(b)
3	Same as cycle 1
4	Same as cycle 2
5	Same as cycle 1
	etc.

This sequence is repeated continually. As shown in the table in Figure 2(a) approximately 2 minutes are required to repeat the sequence. During this time 2 0-32 kyd searches will be obtained, three 0-8 kyd track and doppler sensitive transmissions will be made and three 0-8 kyd highlight sensitive transmissions will be made. A T/C interval would consist of approximately three repetitive sequences and would require about $6\frac{1}{2}$ minutes. Other range scales are shown in Figures 2(b) and 2(c).

A programmer is required to control the sequence of transmissions and to switch the steered beam receiver to the proper processor and display as the No. 3(a) pulse is replaced by the No. 3(b) pulse. The programmer

should be an adjustable device which can be reprogrammed for other range combinations such as the 32-32 kyd, the 32-16 kyd, or the 16-4 kyd scale, whichever is the most suitable for the waters in which the ship must operate. This programming would not be altered except on rare occasions when the conditions of operation change sufficiently to require such alteration and would not be under direct operator control. The programmer is described further in a later section.

Once this mode has been selected, the pulse sequences remain unaltered until authorization is given to deviate from this mode. Only the search displays are used until a contact is made. At this point no change in transmission is made. The operator simply steers the receive beam to the target and begins to accept the track/classify information which is in the water.

The other form of this mode (time-shared form) utilizes the same transmissions but they are transmitted on a time sharing basis rather than a frequency sharing basis (Figure 3(a)). This form reduces the mutual interference between ships, but this reduction is paid for by the increase in time required in carrying out the track/classify function and in the decreased search rate. The sequence is shown in Table V. It is not possible to alternate the 3(a) and 3(b) pulse in this mode because they will not occur uniformly spaced in time.

TABLE V

COMPLETE 32 KYD-8 KYD MODE I(b) SEQUENCE
(Non-Alerting, Time-Shared Mode)

Cycle	Transmissions	Frequency	Timing
1	1 - No. 1, 1 - No. 2	f_1	0-50 sec.
	6 - No. 3(a)	f_1	50-100 sec.
2	1 - No. 1, 1 - No. 2	f_1	100-150 sec.
	12 - No. 3(b)	f_1	150-250 sec.

With this mode the sequence is completed in about 3 minutes, but less is accomplished. This mode requires about 50% longer for a fixed number of search transmissions than Mode I(a). A burst mode consisting of 10 4ms pulses is to be available as a substitute for the 10 3(b) transmissions. The pulse separator is to be suitable for display on a GR with an 800 yard gate.

The primary advantage of this mode is the reduction of mutual interference.

In general targets at ranges greater than 8 kyd (the T/C range scale) would be observed with a range ambiguity interval of 8 kyd. This would be true of both the I(a) and I(b) modes.

A few specific requirements are important in maintaining the non-alerting, information-denying characteristics of this mode.

(a) The RDT is of the normal variety except that it starts on a different bearing on each pulse transmission. This starting point is sequenced to one of eight equally spaced bearing. The RDT beam skips across the baffled stern sector with no time lag.

(b) The RDT should have two adjustable 10° silent sectors, sectors in which no transmission is made. The RDT skips across these sectors with no time lag.

(c) The audio beam will remain on one bearing through a complete sequence but will jump to a new randomly-chosen bearing automatically at the beginning of a new sequence. The particular bearing choice will be the same as that used in Mode II (Modified Non-Alert Modes) in the T/C transmissions. This feature will have manual control in this mode so that the Operator may choose the audio beam direction if he desires.

II. The Modified, Non-Alert Modes

These modes are almost identical to the Non-Alert Modes. For these modes the Track/Classify transmissions shown in Figures 2 and 3 are SLT rather than ODT. The SLT (Searchlight transmission) must be a non-rotating 15° searchlight beam.

Prior to making a contact the SLT bearing is left at a particular setting through a complete sequence (T/C interval) and altered randomly to a new position at the beginning of each new sequence (T/C interval). The same bearing is employed for the audio beam. When a contact is made the operator may force the next choice to be the bearing indicated by the search cursor for one sequence (T/C interval). Maintaining the SLT at this bearing for more than one sequence (T/C interval) will not be possible under this mode for more than one interval in four. To do so would constitute a deviation from the non-alerting condition.

Both frequency-shared (II-(a)) and time-shared (II-(b)) modes will be available.

III. Alerting Modes

(a) Frequency Shared, Operator Controlled SLT Bearing

This mode is identical to Mode II(a) except that the track/

classify transmission bearing is operator controlled. This mode provides the optimum opportunity for tracking while maintaining search.

(b) Time-Shared, Operator Controlled SLT Bearing

This mode is identical to Mode II(b) except that the track/classify transmission bearing is operator controlled.

(c) Low Target Density Manual

In this mode only search transmissions are normally employed until a contact is made. Pulse form, pulse length, and range scale are selectable. The processor and display appropriate for the particular pulse form are automatically selected with the pulse form. When a contact is made selection of a suitable track/classify pulse and range scale can be made by the operator.

E. THE MODE PROGRAMMER

A mode programmer is necessary to provide the operational characteristics required. This programmer should have some versatitlity so that, when the specific parameters listed in the mode descriptions given are not suitable, they can be altered. For example, the descriptions given may be suitable for deep-water, good-layer conditions but entirely unsuitable for shallow water conditions. When operating conditions are to be different for a period of time reprogramming the mode sequences specifically for those conditions is recommended. The selectable items are listed:

Search Choices

1. Pulse length, form, ODT, frequency
2. Pulse length, form, RDT, Range Scale, Frequency

Track/Classify Choices

1. Pulse length for DD,SDS, and GR processing, frequency, alternating or burst highlight pulses.
2. Range scale.

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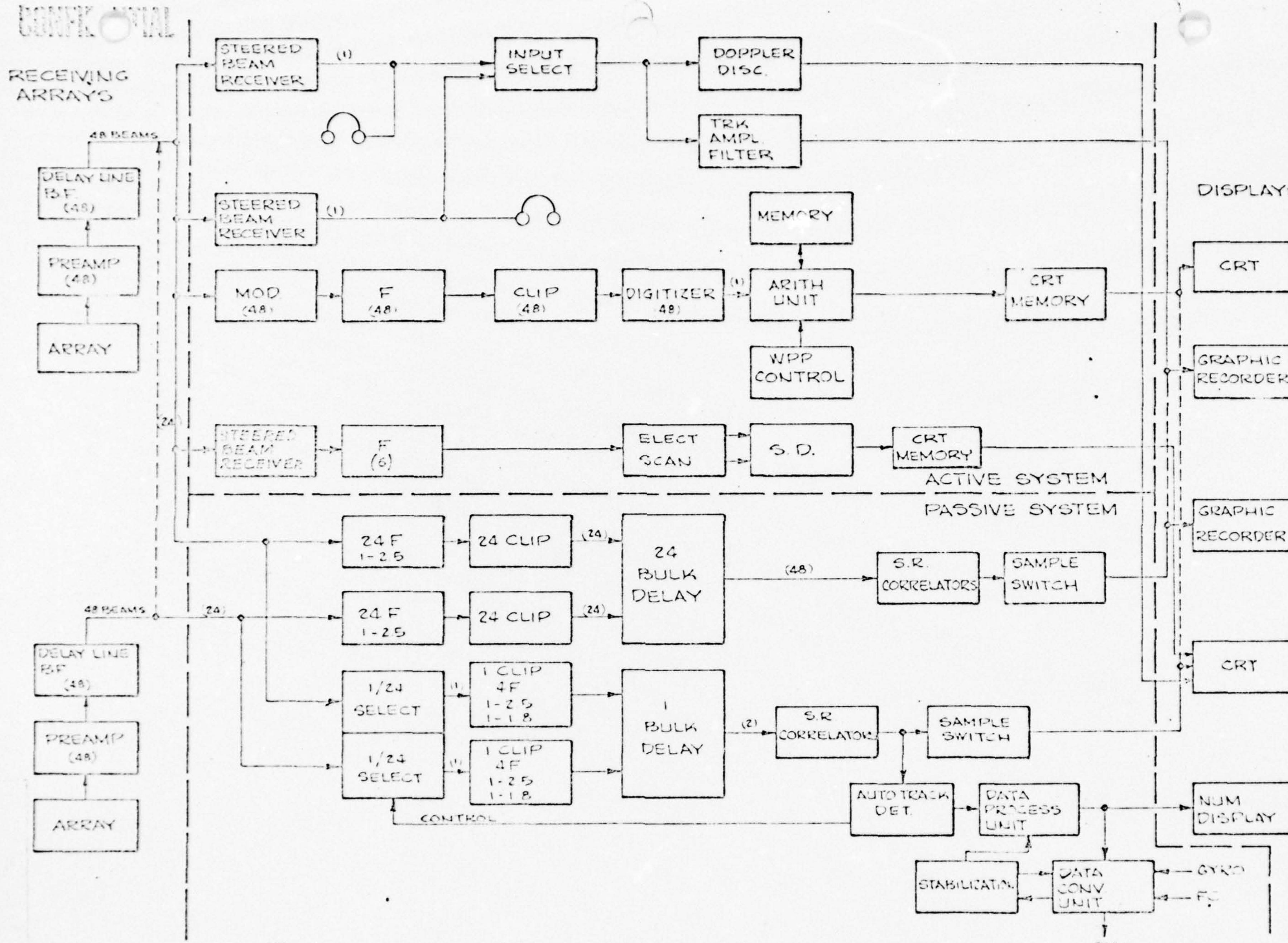

FIG. 1 - RECEIVER BLOCK DIAGRAM

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Task No. 11

TASK II

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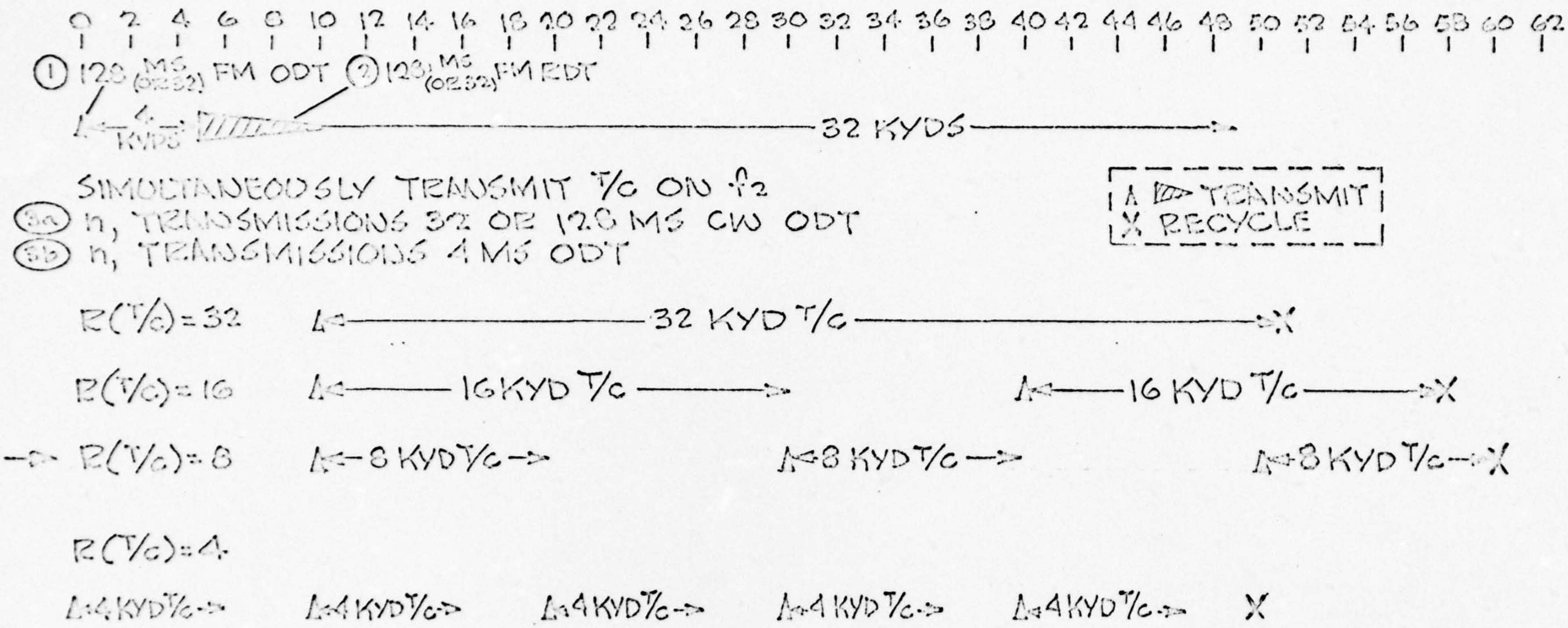
SCALE 32-R(T/C)

TRANSMIT SEARCH ON f_1 (N TRANSMISSIONS PER COMPLETE SEQUENCE) TIME (SEC)



N ODT SEARCH, N RDT SEARCH, n 4MS AND n 32MS TRACK/CLASSIFY PULSES PER T/C INTERVAL

SCALE	N	#4MS	#32 OR 128 MS	TIME PER T/C INTERVAL (SEC)	TIME/ RECYCLE (SEC)	EFFICIENCY T/C	EFFICIENCY S
32-32	20	10	10	960	48.8	80	99
32-16	10	10	10	588	58.4	67	83
32-8	6 2/3	10	10	388	58.8	50	92
32-4	4	10	10	200	50	50	94

FIG. 2 (a) NON-ALERT, FREQUENCY-SHARING MODE
[MODE I (a), SCALE 32-R (T/C)]

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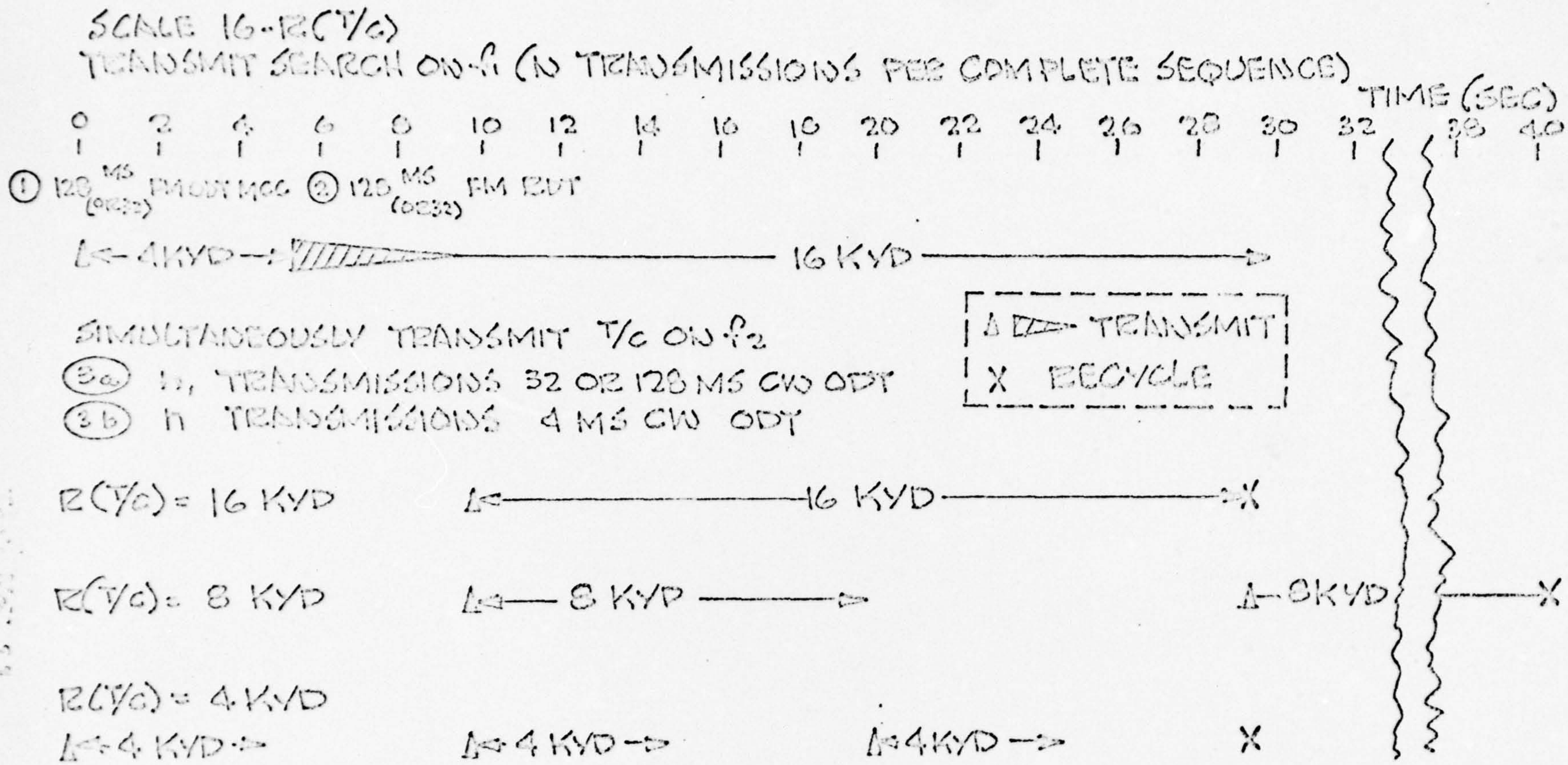
Task No. 11



SCALE	N	#4MS	#32 OR 128 MS	TIME PER T/c INTERVAL (SEC)	EFFICIENCY T/c	EFFICIENCY S
16-16	20	10	10	580	66	96
16-8	10	10	10	384	50	70
16-4	6⅔	10	10	200	50	91

FIG. 2(b)

[MODE I(a), SCALE 16-R (T/c)]

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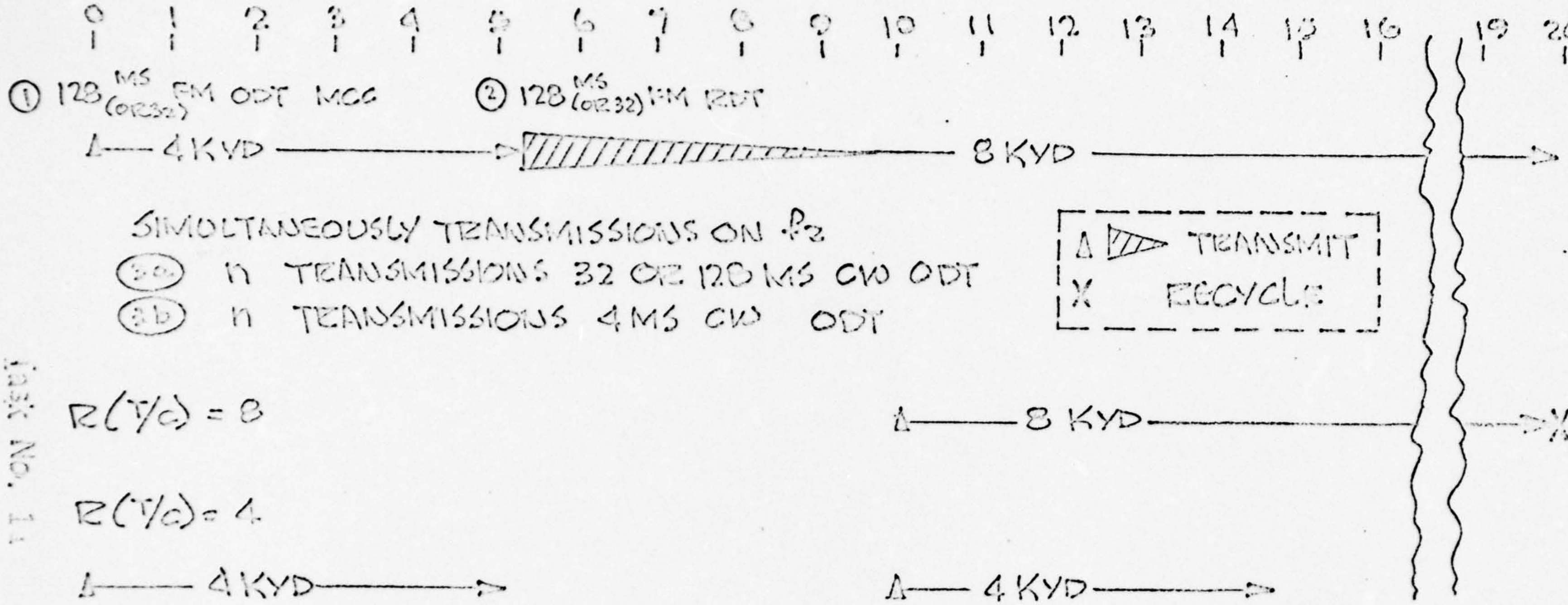
TASK 11

Task No. 11

SCALE 8-R(T/C)
TRANSMIT SEARCH ON f_1 (IN TRANSMISSIONS PER COMPLETE SEQUENCE)



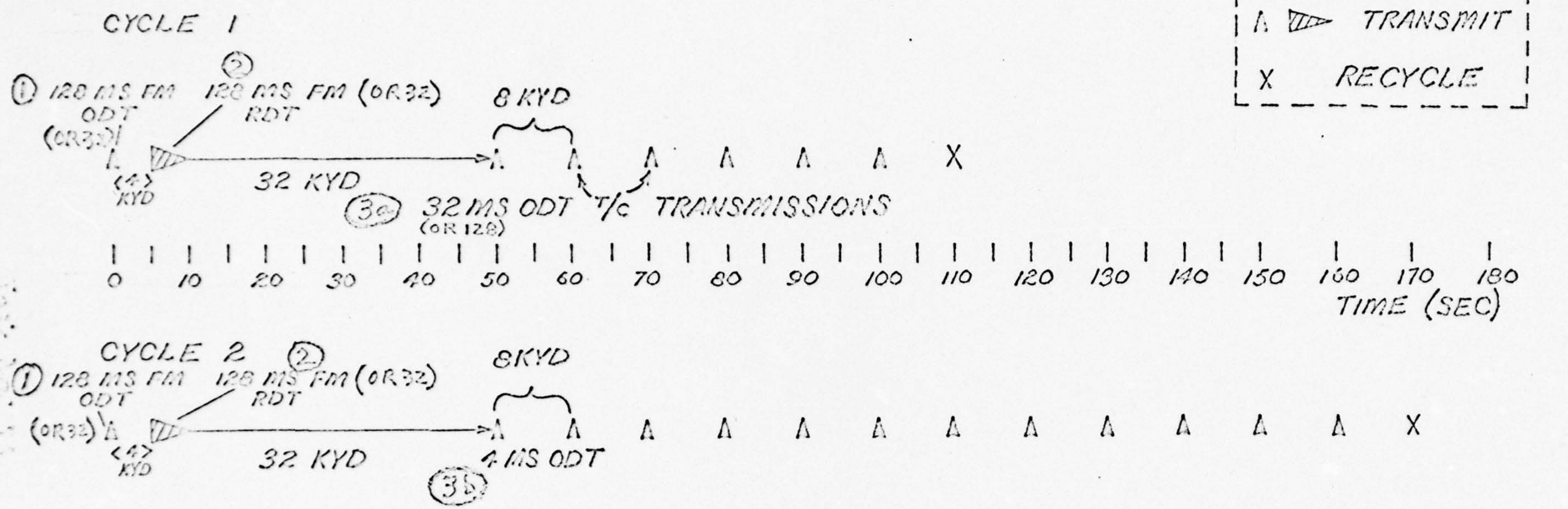
Task No. 11

SCALE	N	# 4 MS	# 32 OR 128 MS	TIME PER T/C INTERVAL (SEC)	EFFICIENCY T/C	EFFICIENCY S
8-8	20	10	10	304	50	99
8-4	10	10	10	200	50	93

FIG. 2 (c)

[MODE I (c), SCALE 8-R (T/C)]

TRANSMIT SEARCH AND TRACK/CLASSIFY PULSES ON THE SAME FREQUENCY
SCALE 32-8



A COMPLETE SEQUENCE CONSISTS OF ONE CYCLE 1 AND ONE CYCLE 2

SCALE	SEARCH TRANSMISSIONS	T/C TRANS.	32ms	4ms	TIME/SEQ	EFFICIENCY SEARCH	T/C
32-8	2	18	6	12	285	0.35	0.65

FIG. 3(a) NON-ALERT, TIME-SHARING MODE [MODE I(b)]

TASK II

CONFIDENTIAL

I. TASK NUMBER: 12

II. TASK TITLE: Stabilization

III. INVESTIGATOR(s): H. Klee, A. Rhiner, R. Crabb and B. Pennoyer

IV. CONCLUSIONS

A. Recommended Changes to the Specification

1. The contract specifications must delineate stabilization requirements in the determination of true target bearing pertaining to fire control, passive track, active track, search light transmission, rotational directional transmission, and all displays.

2. The contract specifications must specify allowable bearing errors, and the conditions under which these errors are determined.

3. The contract specifications must specify the use of a target depression angle control for passive and active track. (See discussion on page 3 of included Discussion.)

B. Suggested Improvements

The wave period processor performance could be improved by providing stabilization corrections to its data; if the cost of including such corrections is not prohibitive.

C. Need for Continued Investigation

1. Studies of signal degradation due to lack of vertical beam stabilization could be continued. Such information could be useful in analyzing the performance of the AN/SQS-23 Sonar System in various sea states.

2. The wave period processor data has no stabilization corrections for pitch and roll. Information regarding the effects due to lack of the corrections would be informative, and should be obtained if the active search display is simulated.

V. DISCUSSION

A. Stabilization Technique

Any motion about a ship's coordinate axis is converted into syncro signals by its gyro compass. The synchro signals contain electronic information which includes all variations in pitch, roll and ship's heading relative to true bearing. The stabilization that exists in the AN/SQS-23 (PAIR) Sonar System is a function of some or all of the synchro information. This information is processed in the sonar system computer, the Data Processing Unit (DPU).

The Data Processing Unit (DPU) computes solutions for two equations of stabilization correction of which one equation is for the passive mode and the other for the active mode. The resultant solution of these equations is a correction in relative beam bearing. The stabilization computation does not provide correction for a change in the vertical beam angle due to ship's motion. The active stabilization equation contains four variables; pitch, roll, target depression angle and initial relative target bearing. The passive equation is a function of pitch, target depression angle, initial relative target bearing and signal time delay between the two receiving hydrophone arrays. Roll has no effect on the solution of the passive equation as long as the hydrophone arrays are mounted parallel to the ship's keel.

There is one variable in both equations for which the gyro compass does not provide values. It is the target depression angle. Since there is no value provided, its value will be considered zero degrees. However, the study program by Sperry proposes a target depression adjustment on the passive track display which can provide values of target depression angle. The adjustment value would be determined by the sonar operator. The operator

determines the correct adjustment by the amount of jitter in the target indication on the display. The point of minimum jitter is considered the correct value of depression angle. This same value can be used in the active stabilization equation.[1] The jitter is dependent on the pitch of the ship. If the ship is not pitching, there would be no jitter, and hence, no value of target depression angle could be determined.

Once the equations have been computed, the corrections are made on the following active and passive operations.

1. Active: Rotational Directional Transmission[1]
   Search Light Transmission
   Active Target Tracking
2. Passive: Passive Target Tracking

The corrections are accomplished by changing the beam selections so that there is a beam in a specific horizontal area of the ocean regardless of ship's motion due to pitch and roll.

Another operation performed by the Data Processing is to provide signals which make <u>all</u> displays true bearing stabilized. As a result all operations would have yaw stabilization.

B. <u>Stabilization Technique Evaluation</u>

The stabilization technique that is proposed makes stabilization corrections in relative target bearing angles only. Since there is no vertical beam stabilization, bearing errors and signal degradation can be produced by pitch and roll of the ship. As a ship rolls and pitches, it is possible for a transmitted beam to miss its target or the return signal to miss the receiving beam if the resultant motion causes the ship's deck plane to tilt more than 6° from the horizontal. If the target depression

angle is a few degrees, the resultant deck plane motion does not have to be 6° to have considerable error or signal degradation. To say that a signal sequence will be lost entirely is an unfair evaluation because more than a one ping sequence will be transmitted or received. By using pitch and roll tables of a DL-5 Class Destroyer, a rough estimate[2] of signal degradation can be determined. This signal degradation would be a function of pitch, roll and percent time that the ship is in various sea states. For a mean value of pitch and roll, a transmitted and received signal can be degraded by 2.26 db on a long ping sequence basis. If the maximum pitch and roll conditions are used, the same signal is degraded by 19.3 db. Also, a short ping sequence could produce greater signal degradation.

This problem, of signal degradation should be a continued study. It should be attacked from a statistical basis of the ship's true motion and for a realistic ping sequence.

The same type of signal degradation that occurs in the active mode can also be produced in the passive mode. However, the passive signal will not be degraded as severely, because of the increased vertical beam width. The minimum passive vertical beam pattern is approximately twice as wide as the maximum active beam. Hence, the ship's motion can produce larger excursions from the horizontal plane with less effect on the passive received signal.

As for the bearing errors caused by the ship's motion, two factors of stabilization contribute to them. One is the lack of vertical beam correction and the other is that no method to determine target depression angle exists. Nothing will be done about the vertical beam correction and its maximum resultant bearing error is 3 degrees at maximum sea state 4 conditions.

However, the target depression angle cannot be ignored for its value is required by the Data Processing Unit in its computation of the stabilization equations.[3] There is no direct method for determining the target depression angle. The value used in the computation will be zero degrees or that value determined by the sonar operator as previously described. Serious drawbacks which occur by this method of determining the target depression angle are: (1) In order to d etermine target depression angle, the target must be detected in passive track, because no other operating mode can supply this information. (2) Lack of pitch by the ship produces no jitter, hence, the operator does not know what value to provide in the computations, therefore bearing error will be produced. If the value used for the computation is nay value other than the real target depression angle, bearing error is produced. For maximum roll and pitch conditions of sea state 4 of a DL-5 ship, a real target depression angle of 10 degrees and a value of zero degrees for target depression angle used in the computation of the active stabilization solution a maximum bearing error of 3.7° is produced.[4] As the target depression angle differs and pitch and roll angles decrease, so does the bearing error. For the same conditions as stated above, the passive solution can have a maximum bearing error of 10°. If the target depression angle is used, the 10° error would be reduced.

Another two operations which are plagued by bearing errors are passive and active search. These operations have no pitch and roll stabilization. As a result, with maximum sea state 4 conditions and real target depression angle of 10°, the active operation can have a maximum of 6.2 degrees bearing error. If the target return signal conditions are just right, any motion due to pitch and roll can cause the display beam to jump bearing bins, and the 6.2 degree shift will definitely do so. The degree of display degradation caused by the bearing bin jumping is beyond the scope of

this memorandum. This is one of the problem areas for which further studies should be planned. The same type of display degradation can plague the graphic recorders which work in conjunction with the steered beam receiver and the search mode of PADLOC.

Finally, all operations will be stabilized to true bearing. True bearing stabilization is provided on all displays. The only bearing error due to this stabilization of the displays will be that produced by the equipment which converts synchro signals into electronic pulses and back to synchro signals. The proposed display stabilization method and equipment will produce less than 0.04 degrees error which is negligible.

C. Specifications Evaluation

The latest specifications booklet is rather ambiguous in delineating the requirements of stabilization for the AN/SQS-23 (PAIR) Sonar Program. There is no direct specification of stabilization, its techniques or its error tolerances. However the specifications booklet does imply the following about stabilization.

1. The Data Processing Unit shall be capable of computing coordinate transformation for passive and active track, and also perform the necessary operations which will stabilize all displays to true bearing.

2. Track ball and cursor circuits shall generate bearing data for fire control and steered direction transmission.

3. The sonar system shall be compatible with fire control and the gyro compass.

4. In the active track difference mode, there shall be less than 0.4° error in bearing data with an infinite signal to noise ratio.

5. In the passive mode, there shall be less bearing error than shown in Figure 3 of the latest specifications booklet.

APPENDIX

1. As per conversation with Sperry Gyroscope Company (Mr. Robert Knox) of 3 September 1965.

2. See computation sheet.

3. a.

$$\Theta = \text{arc tan}\left[\frac{\text{Cos } d \text{ Cos } r \text{ Sin } Ba - \text{Sin } r(\text{Sin } d \text{ Cos } p - \text{Cos } d \text{ Cos } Ba \text{ Sin } p)}{\text{Sin } d \text{ Sin } p + \text{Cos } Ba \text{ Cos } p}\right]$$

where

Θ is corrected relative bearing in degrees from bow of ship

r is roll angle in degrees toward starboard from vertical

p is pitch angle in degrees up from horizontal plane

d is target depression angle in degrees--up is positive angle

Ba is initial relative bearing.

3. b.

$$Ba = \text{arc cos}\left[\frac{v}{l}\left[\frac{t_1 - \frac{l}{v} \text{ Sin } p}{\text{Cos } p \text{ Cos } d}\right]\right]$$

where

v is velocity of sound in water

l is spacing between arrays

t_1 is time difference between arrays

4. This value 3.7° was determined from computer solution of 3.a for angles of pitch and roll of sea state 4.

EVALUATION OF SIGNAL DEGRADATION

Method as proposed by Dr. Bob M. Brown of TRACOR, Inc. for rough estimate. Signal degradation determined from vertical beam patterns.

Sea State	Percent Time in Sea State	Roll Angle (degrees) Mean	Maximum	Signal Degradation for Given Roll Angles (db) Mean	Maximum
1	35%	1°	5°	0	2.5
2	29%	2°	10°	0.5	12
3	18%	4°	15°	1.5	15
4	15%	6°	20°	3.0	15
5	3%	13°	22.5°	13	15

Sea State	Percent Time x Signal Degradation (one way loss) Mean	Maximum
1	0	0.875
2	0.14	3.5
3	0.27	2.7
4	0.4	2.25
5	0.32	0.45
TOTAL DEGRADATION	(2) (1.13)	(2) (9.65)
TWO WAY LOSS =	2.26 db	19.3 db

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I. TASK NUMBER: 13

II. TASK TITLE: Active Array

III. INVESTIGATOR(s): H. J. Klee (prepared by R. A. Klug)

IV. CONCLUSIONS

A. Recommended Changes to the Specification

1. An analysis must be made of the proposed transducers, i.e. (1) TR-208 (Massa), (2) TR-191 (Harris), (3) TR-197 (Raytheon), (4) TR-177 (Sangamo) and (5) TR-152 (Bendix), when driven by a TRAM transmitter. This is necessary because of the different operating requirements of PAIR compared to the basic SQS-23 operation. The PAIR requirements are so changed that previous accepted performance levels cannot be guaranteed for the new operating requirements without this analysis. PAIR source levels, beam patterns, and reliability of the transducer/transmitter must be confirmed as obtainable, with the existing transducers and TRAM transmitter. This should be accomplished before the final contract is signed. If not, there must be an understanding that failure to meet the PAIR requirements by the transducer/transmitter configuration would necessitate modification of the PAIR requirements or possibly the design of a new SQS-23 transducer. (Reference attached memorandum by John Hickman, Code 3160, Transducer Division Head)

B. Suggested Improvements

It is possible because of the large head size of each transducer element (approximately one-half wave length) that some form of velocity control exists. The proposed TRAM transmitter will drive either 4 or 5 transducer elements connected in parallel. It is recommended to change the parallel connection to a series connection to take advantage of the high output impedance of the amplifier and the constant current drive to increase the degree of velocity control.

DOWNGRADED AT 3-YEAR INTERVALS
DECLASSIFIED AFTER 12 YEARS
DOD DIR 5200.10

Enclosure (13)

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C. Need for Continued Investigation

If the complete set of empirical tests with all transducers and all equipment cannot be made, a complete mathematical analysis should be made to determine if increased velocity control with the transducer/transmitter complex is necessary. Then prior to a production contract it will still be essential to make a thorough at sea empirical analysis.

V. DISCUSSION

The documents "SHIPS-T-3878B" and "SHIPS-T-4854" on the Harris TR-191, Sangamo TR-177 and the Massa TR-208 transducers state that these transducers should be capable of a 500 watt electrical input for 0.5 seconds with a 9.5 second OFF period. This indicates a duty cycle of 0.05 with an average input of 25 watts.

To maintain a source level of 135 db/μbar in the 128 millisecond, 300° RDT mode of operation (worse case), each transducer element will have to accept 15.0 watts average input power for the 50% efficient units and 24.7 watts average for the 30% units (Figure 2). All the transducers can handle the required power at 5 kc, however, TR-197, TR-177 and TR-152 fall to efficiencies less than 30% within the proposed operating frequency range thus making the required input power too great for the long duty cycle required.

Review of all available information on the five (5) transducer models proposed for use with PAIR indicates that the Harris TR-191 and Massa TR-208 transducers are most apt to be suitable. Single element and 3 x 3 array frequency response curves are available for the Harris TR-191, Raytheon TR-197 and Massa TR-208 transducers. These curves may or may not be valid for the entire array responses. The curves for TR-191 and TR-208 are

relatively flat above 4.5 kc, however, the TR-197 has a response peak at 5.0 Kcps. The extreme limits of each operating band differ by about 3 to 4 db. Simulation studies indicate that this variation may be tolerable to the Wave Period Processor, but a 12 db difference is enough to completely destroy the processor output. Frequency response curves were not available for the Sangamo TR-177 or Bendix TR-152, however, the specifications for these transducers indicate that they will have a peaked response like that of the Raytheon TR-197.

The stated efficiency of the Harris TR-191 and Massa TR-028 transducers is greater than 60%. Specifications for the Sangamo TR-177, Bendix TR-152 and Raytheon TR-197 require only 30%. Since the TRAM modification reduces the power handling capabilities of the transmitter section, the lower efficiency of the later group would require operating the amplifiers above 70% of maximum capability to maintain satisfactory source level (Figure 1). This additional load will reduce the transmitter reliability.

There are no specific measurestaken in the AN/SQS-23 or the TRAM modification to insure velocity control of the active array. In fact there is no information available regarding the degree of velocity control inherent to the unmodified array. Additional studies should be instituted to determine if increased velocity control is needed. If more velocity control is required the study will have to determine what, if any, measures can be used to accomplish this goal. An investigation to determine the cause of the internal acoustic reflections present in the Massa TR-208 and possibly the Harris TR-191 transducers should be undertaken. The cause and cure of these reflections should be known so that proper action can be taken to eliminate the problem.

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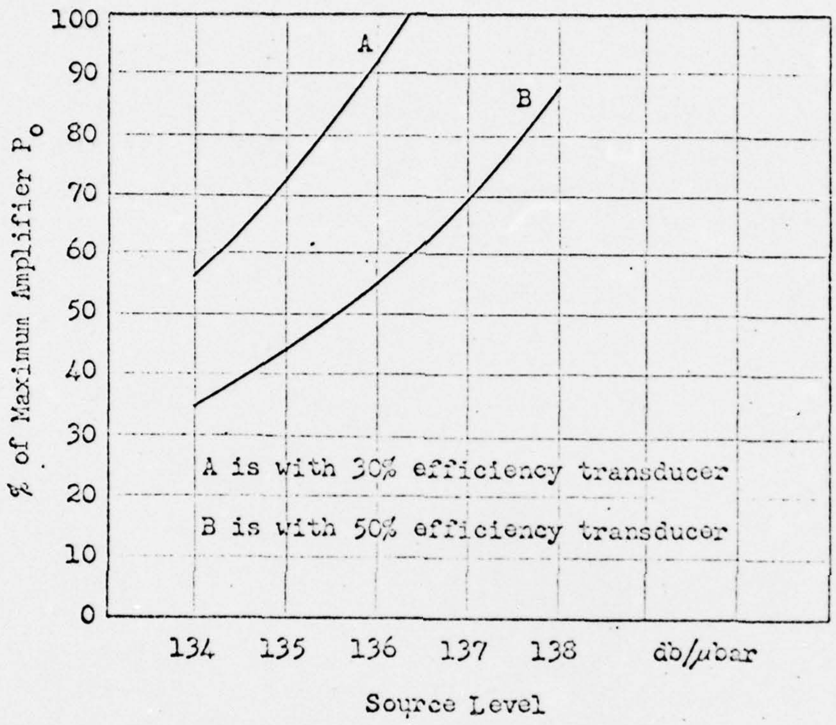

Figure 1

Percent of Maximum Amplifier Power Used
versus
Source Level

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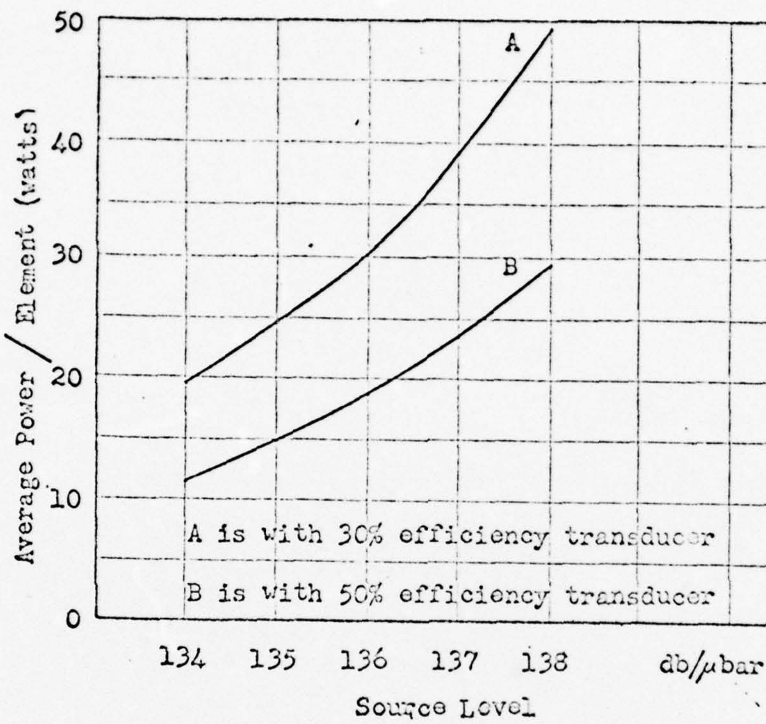

Figure 2

Average Drive / Transducer Element
versus
Source Level

1 September 1965

MEMORANDUM

From: J. S. Hickman, Code 3160
To: Harvey Klee, Code 2140

Subj: NEL's SQS-23 Program; comments concerning

1. As an opening statement, I would like to reiterate what you told me yesterday. As defined by BUSHIPS, NEL's SQS-23 Program is concerned with the analysis of the processing equipment, built by Sperry, which interfaces with the transducer-transmitter complex. This complex is to be GFE - the improved transmitter (called TRAM) to be built by Sangamo and the transducer to be built primarily by Harris and Massa with some hazy contributions by others.

2. The specific areas of concern are, that to your knowledge:

(a) No one is addressing himself specifically to the vitally important interface of the transmitter and transducer.

(b) No investigations have been made to determine whether or not, and over what bandwidth, the transducer array has velocity control in the present mode of operation. This is of even greater concern because in the retrofit equipments, the bandwidth requirements may be greater. Parenthetically, 'they' say this is feasible because the 'Q_e Q_m' bandwidth is broad enough - but what is the velocity control bandwidth?

(c) The transducer was hypothesized as being adequate on the basis of source level and directivity patterns. To date, no one at NEL has been able to pin down where, how and on what kind of transmitter-transducer complex these 'adequate' measurements were made. (A pertinent comment here is that even if NEL confirmed the validity of such measurement, our theory and experience with arrays proves that all hell can be breaking loose transducer-wise without very much change in these measurements).

3. When NEL accepted this program, the Transducer Division was informed that it would not be concerned with it. And, in fact, if one accepts the hypothesis that this GFE equipment is A-OK by NEL standards this is true. But we have already begun to be involved by your and Dr. Burbank's very real concern about this hypothesis and your subsequent request of inputs from us in this area. I must, therefore, go on record as completely agreeing with your fears. The fact that the Navy would accept at this late date another transmitter-transducer complex without complete assurance of velocity control, performance prediction, and rigorous calibration is unbelievable.

Task No. 13

4. What is the Transducer Division to do? Unless this is a very unusual situation, nothing short of a full-blown analysis of the element and array will give you the answers you need. In the case of the SQS-26, this type of analysis took all our scientific personnel over four months on a crash basis. Even if we had nothing else to do (which is a large joke considering our 100% current over-commitment), we could not possibly supply you with this type of information within your time frame. What we might hope to do, however, is to point out the facts of paragraph (2) to appropriate people here and at BUSHIPS and hope that they will be as frightened as we are. Maybe that would prevent another fiasco.

J S Hickman

J. S. HICKMAN
Head, Transducer Division

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I. TASK NUMBER: 14

II. TASK TITLE: Wave Period Processor (WPP)

III. INVESTIGATOR(s): H. Klee, B. Hart

IV. CONCLUSIONS

A. Recommended Changes to Specification

The specifications covering the Wave Period Processor must be modified as indicated in the following paragraphs.

1. Correct paragraph 3.3.1.1.1 to read:

a. . . . Transmission of 4 ms, 32 ms or 128 ms pulse lengths in the CW Mode "with the frequency centered at either 4.5 kc or 5.5 kc".

b. . . . Transmission of "32 ms or 128 ms pulse lengths" of a linear FM slide over a band of 400 cps "centered either at 4.5 kc or 5.5 kc" shall be a minimum of 135 db.

c. . . . shall be 120 db "for pulse length of 4 ms, 32 ms, or 128 ms with the frequency centered at either 4.5 kc or 5.5 kc".

2. Change paragraph 3.4.4.3.2 to read:

. . . ± 200 cps about the center frequency. "The slide time shall be 128 ms for the 128 ms pulse length and 32 ms for the 32 ms pulse length".

3. Add to paragraph 3.4.5.1.4 the following part:

(f) "The attenuation must roll off to 100 db as specified and must never become less than 100 db anywhere within the passband of the transducer. Outside of the transducer's passband the combined attenuation of the filter and transducer must always be at least 100 db."

4. Correct paragraph 3.4.5.3 to read:

a. The unit shall be capable of processing the "128 ms" CW pulse "and both the 128 and 32 ms" FM slide pulses "from high frequency

to low frequency, or from low frequency to high frequency" as specified in 3.4.4.3.

b. (b) 48 clippers "with line drivers".

c. (i) "output memory unit"

5. Change paragraph 3.4.5.3.3 to read:

a. Each of the 48 digitizers shall contain a "16" period timer......

b. The "16" period timer shall generate a gating pulse for the duration of "16" periods . . . .

c. Add part (d) "Each digitizer is sampled in sequence and reset by the timing control unit every 1.11 milliseconds."

6. Change paragraph 3.4.5.3.4 to read:

The timing accuracy of all frequencies supplied "by" the TCU . . .

7. Change paragraph 3.4.5.3.6 to read:

Zone digit accumulation "of 128 stored samples for the 128 millisecond transmission or of 32 stored samples for the 32 millisecond transmission" and shall also control. . . .

8. Change paragraph 3.4.5.3.7 to read:

The control shall be accomplished by storing two (2) 24 sample accumulations "on the 128 millisecond transmission" for each of the 48 input channels.

B. Suggested Improvements

1. Incorporate target level compensation for the 32 millisecond mode if possible.

2. ODN (Own doppler nullification should be provided on both transmit and receive. This would permit use of CW for ODT (Omni Directional

Transmission). It would also eliminate the error in ODN (Transmit only) caused by maneuvering.

3. Target Doppler Nullification would provide full processor gain from the Wave Period Processor for high doppler targets when using the FM Transmission Mode. (See Graph #2).

C. Need for Further Investigation

1. The feature of electronic ping-to-ping integration could be accomplished in the display memory with some additional cost and effort. Continued analysis would be necessary to determine if any improvement over the ping-to-ping integration obtained on the CRT (Cathode Ray Tube) could be noted and that if this improvement would justify the addition.

2. Criteria for extrapolating ROC curves for low false alarm rates should be obtained. TRACOR has the computer program for accomplishing this task with a minimum amount of effort.

3. No target level compensation on the 32 millisecond FM transmission mode is provided. Little anticipation of the measured signal-to-noise ratio is provided when 24 of the 32 counts are used for this feature. Additional analysis is needed to optimize the number of counts to provide adequate target level compensation in the 32 multisecond FM mode.

V. DISCUSSION

The technique of Wave Period Processing was developed under Navy Contract NObsr 77614, as part of a program to further the state-of-the-art in sonar signal processing. This method of signal processing uses only the information contained in the wave period or axis crossover points, as the amplitude information is lost due to clipping. By storing this wave period

information and computing certain statistical properties of this stored data, an output solution can be provided.

The Wave Period Processor (WPP) will be able to function on both the CW and FM modes. The primary mode will be the 128 or 32 millisecond FM pulse with a linear frequency sweep of ± 200 cps about the center frequency. The secondary mode will be the 128 millisecond CW pulse, which is more effective than the FM mode for weak signal, high doppler targets in the reverberation phase of the return signal.

A. Subsystem Requirements

1. The WPP will consist of 48 target level-compensation mixers, 48 clippers with line drivers, 48 digitizers, a Timing Control Unit (TCU), a Magnetic Core Memory (MCM), an Arithmetic Unit (AU) and an Output Memory Unit (OMU). If all the subsystems listed above adhere to the specifications, the WPP should meet its performance requirements.

2. Target level-compensation - The target level-compensation was initially intended for the 128 millisecond pulse transmission and no provision has been made for target level-compensation during the 32 ms transmission pulse. This area should be recommended for continued investigation. Cook Electric Company has indicated a need for future investigation of target level-compensation on the 32 ms FM pulse transmission.

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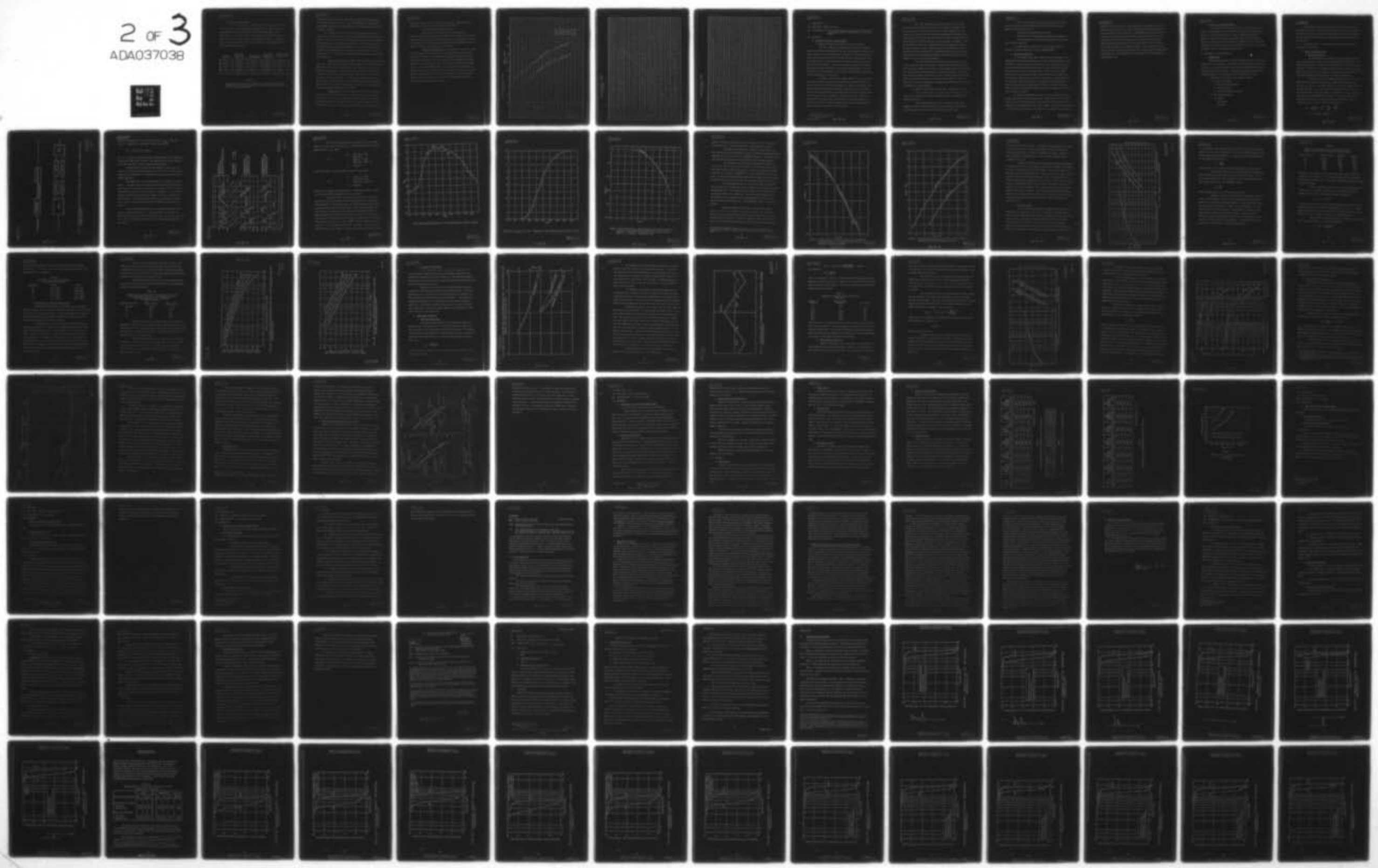

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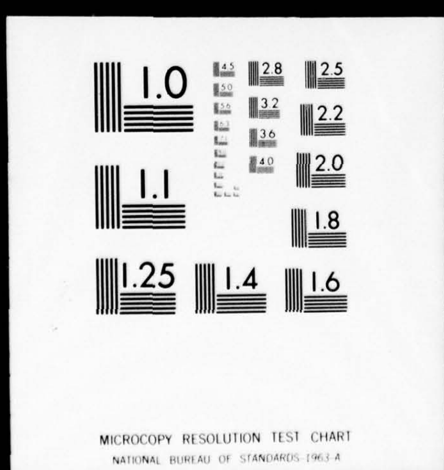

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B. Performance Requirements

1. To establish certain theoretical performance capabilities the WPP was simulated on a digital computer by TRACOR, Inc. Some changes and assumptions were made for the benefit of the simulation process but in basic theory the simulation process agrees fully with the operation of the WPP. The results of the simulation are shown below in Table I. Included in Table I, for comparison, are the two (2) performance requirements given in the revised specifications.

Range Scale in Kyd	Theoretical Simulation $(S/N)_{IN}$ 128 ms	Specifications $(S/N)_{IN}$ 128 ms	Theoretical Simulation $(S/N)_{IN}$ 32 ms	Specifications $(S/N)_{IN}$ 32 ms
32	-1.3 db	+0.3 db	+5.3 db	+7.3 db
16	-1.5 db	------	+4.8 db	------
8	-1.9 db	------	+4.0 db	------
4	-2.3 db	------	+3.3 db	------

TABLE I.

Average signal to noise ratio required at the input to the WPP for 5 background events per display cycle to provide a detection probability of 50% FM mode of transmission.

From Table I it can be seen that the specifications allow approximately a 2 db safety factor in both cases. From this standpoint, the performance requirements given in the specifications are well within reason and should be easily attainable.

2. Signals were added to the noise at various signal-to-noise ratios, into the simulated WPP and the resulting processing gain curves are plotted in Graph #1. Also shown for comparison in Graph #1 are the theoretical processing gain curves furnished by Sperry. It is apparent that the processing gain curves for BT (Bandwidth, Time) = 50, derived from both the Sperry and TRACOR models of the WPP, agree within certain limits. The Sperry data for BT = 12.5 was not available but the predicted curve is shown as a dashed line.

. Own Doppler Nullification (ODN) - ODN is provided on transmission only. This means that two-way doppler is compensated for at the transmission frequency and providing the ship keeps the same heading the return signal will be correctly ODN'd. If the ship maneuvers, the error in ODN will be a function of the change in ship's heading. This error will not have any noticeable effect on the FM mode. In the CW mode this error will show up in the output solution as false targets. In the omnidirectional transmission (ODT), no ODN can be provided. Therefore, as far as the WPP is concerned, only FM transmission pulses will work in ODT.

Target Doppler - In the CW mode, the WPP has more processing gain as the target doppler increases. In the FM mode the processing gain starts to decrease for target dopplers in excess of 5 knots. This decrease in processing gain versus target range rate is shown in Graph #2. For an average target range rate of 30 knots it can be seen that from Graph #2 the

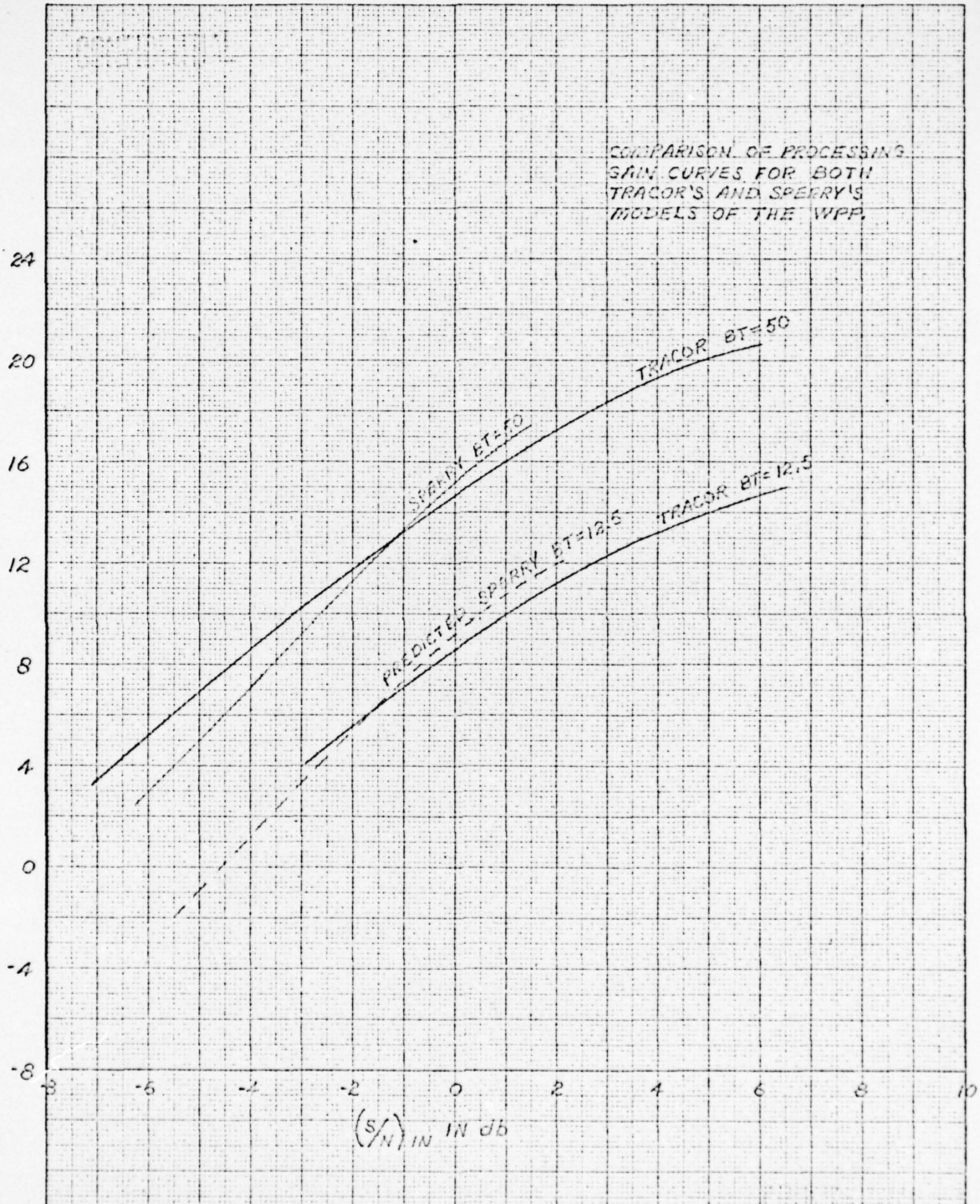
decrease in processing gain of the WPP is only 1 db. This decrease in processing gain could be corrected in one of two ways:

(a) Target Doppler Nullification or

(b) Increasing the bandwidth of the input filters.

The first method would be the most satisfactory as increasing the bandwidth would cause mutual ship interference problems. It is questionable whether a 1 db improvement in processing gain would justify the additional cost and effort of providing target doppler nullification.

Mutual Ship Interference - The criterion for worst case mutual ship interference is calculated for a range of 1000 yards between ships traveling at 30 knots. Maximum doppler spread occurs for the two ships when they are traveling in the same direction with a receiving main lobe looking at a transmitter side lobe. This maximum spread is approximately 400 cps. The above conditions require the filters to be down 100 db or greater at the maximum FM doppler frequency spread. The above data and the frequency characteristics of the proposed filters are shown in Graph #3. From this graph it can be seen that the filter characteristics given in the revised specifications are adequate.



COMPARISON OF PROCESSING GAIN CURVES FOR BOTH TRACOR'S AND SPERRY'S MODELS OF THE WPP.
TRACOR BT=50
SPERRY BT=50
TRACOR BT=12.5
PREDICTED SPERRY BT=12.5
(S/N)OUT IN db
(S/N)IN IN db
24
20
16
12
8
4
0
-4
-8
-6
-4
-2
0
2
4
6
8
10
GRAPH 1

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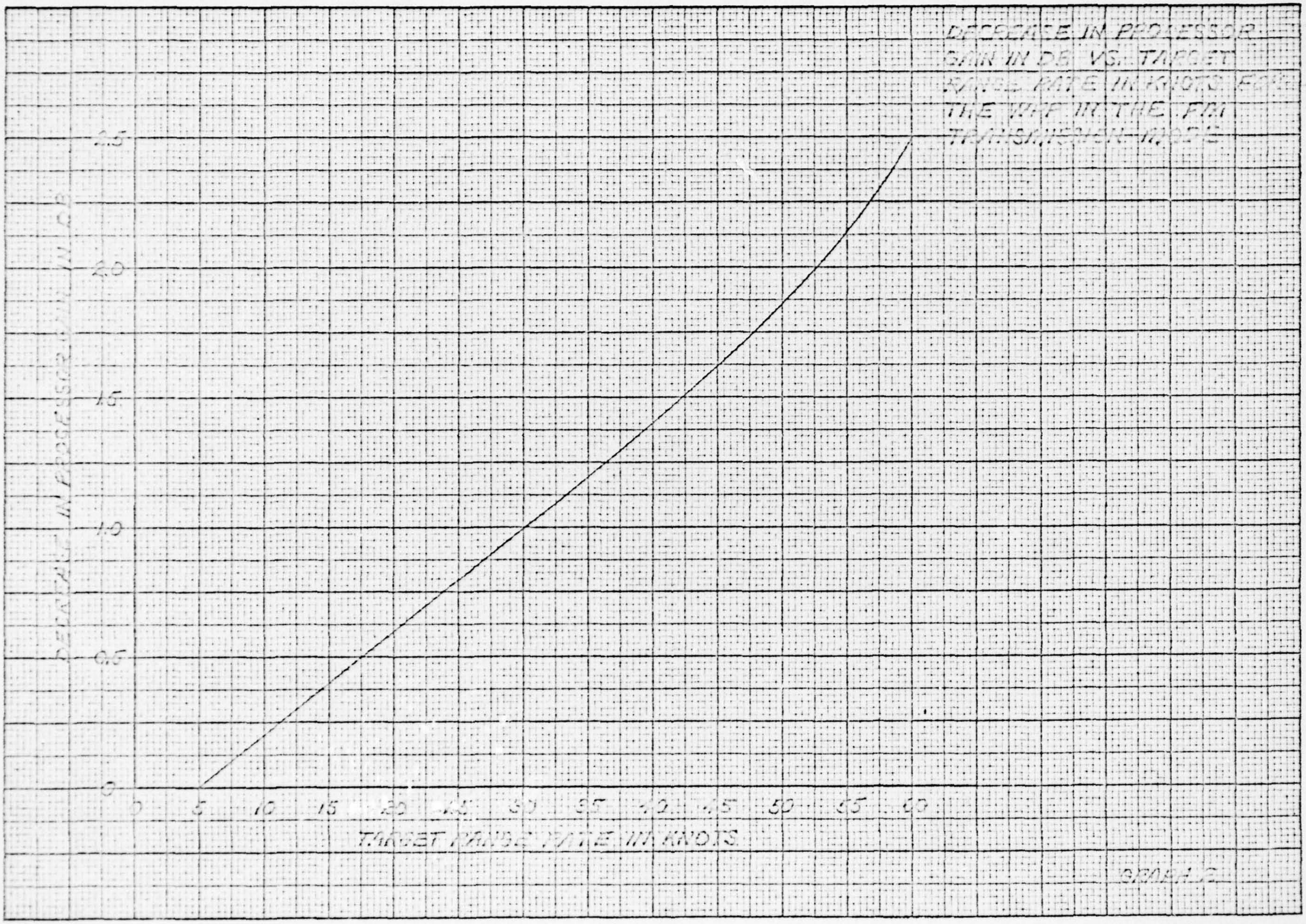

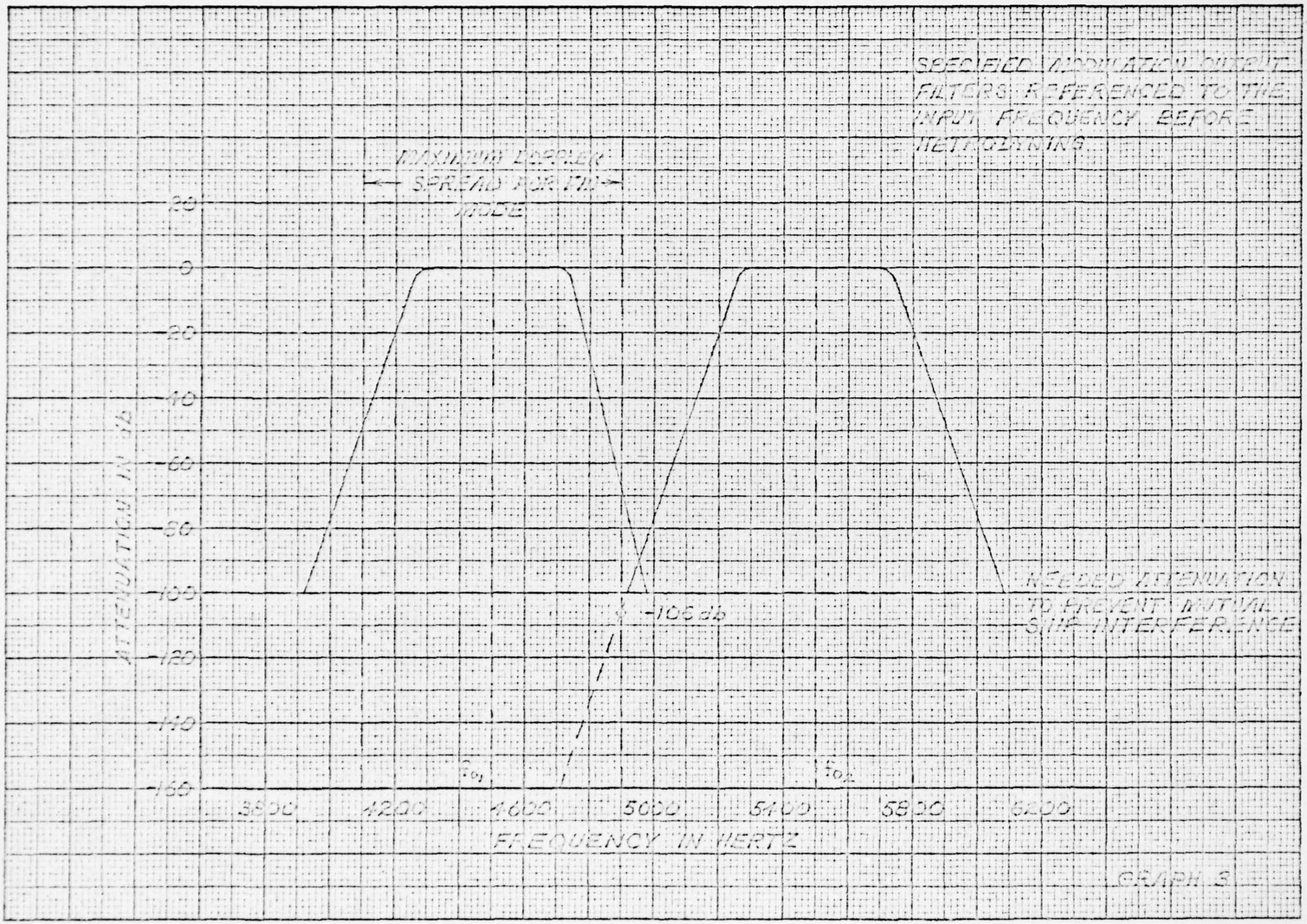
SPECIFIED MODULATION OUTPUT FILTERS REFERENCED TO THE INPUT FREQUENCY BEFORE HETRODYNING
MAXIMUM DOPPLER
← SPREAD FOR FM →
MODE
20
0
-20
-40
-60
-80
-100
-120
-140
-160
ATTENUATION IN db
-106 db
NEEDED ATTENUATION TO PREVENT MUTUAL SHIP INTERFERENCE
f_{o1}
f_{o2}
3800
4200
4600
5000
5400
5800
6200
FREQUENCY IN HERTZ
GRAPH 3

I. TASK NUMBER: 15

II. TASK TITLE: Signal Processing

III. INVESTIGATOR(s): W. E. Klund (with assistance from A. F. Wittenborn, H. R. Courts, TRACOR. Prepared by Dr. B. M. Brown, TRACOR)

IV. CONCLUSIONS

A. Recommended Changes to Specification

1. Replace Section 3.3.1.1.3(b), (c), (d) and (e) with:

(b) "WPP - 128 ms FM pulse (32 kyd scale) with an input rms signal to rms noise ratio introduced into the active clipper amplifier of not more than plus 0.3 db, the probability of a return in the range bearing bin containing the simulated echo shall be 50%, and on the average there shall be 5 marks in range bearing bins outside the one of interest when only one ping interval is completed. This is not intended to define the threshold setting (and marking rate) when in the 5-ping integration mode. The noise referred to in this paragraph shall be Gaussian with bandwidth characteristics as specified in 3.2.2.4.2.(b)."

(c) "WPP - 32 ms FM Pulse (32 Kyd scale) - With an input rms signal to rms noise ratio introduced into the active clipper amplifier of not more than plus 7.3 db, the probability of a return in the range bearing bin containing the simulated echo shall be 50%, and on the average there shall be 5 marks in the range bearing bins outside the one of interest when only one ping interval is completed. This is not intended to define the threshold setting (and marking rate) when in the 5-ping integration mode. The noise referred to in this paragraph shall be Gaussian with bandwidth characteristics as specified in 3.2.2.4.2.(b)."

(d) "WPP - 128 ms CW pulse (8 kyd scale) - With an input rms signal to rms reverberation ratio of not more than the amounts indicated in Figure 2 introduced into the active clipper amplifier, the probability of a return in the range bearing bin containing the simulated echo shall be 50%, and on the average there shall be 5 marks in range bearing bins outside the one of interest when only one ping interval is completed. This is not intended to define the threshold setting (and marking rate) when in the 5 ping integration mode. Figure 2 holds for a reverberation limited background with the reverberation to broadband 470 cps noise ratio greater than +30 db, and the reverberation spectrum is Gaussian shaped with a bandwidth of 12 cps at the half power points."

(e) "Sum Difference Scanner 32 ms CW pulse (32 kyd scale) - In the search mode, when an rms signal to rms noise ratio of not more than plus 11.3 db is introduced at the input to the scanning switch, the probability of a return in the range bearing bin containing the simulated echo shall be 50%, and on the average there shall be 5 marks in range bearing bins outside the one of interest when only one ping interval is completed. The noise referred to in this paragraph shall be Gaussian with bandwidth characteristics as specified in 3.2.2.4.2.(b)."

2. Replace Section 3.3.1.2.2.(b) with: "3.3.1.2.2.(b) Passive

The rms input signal to rms input noise ratio shall not exceed minus 9 db at the input to the passive clippers under the following concurrent conditions:

(a) a threshold level has been established at the search integrator scanner output which will pass on the average only the outputs of four integrators exclusive of the one containing the signal.

(b) The input signal level has been adjusted to cause the integrator containing the correlogram peak to exceed the established threshold level 50% of the time.

(c) One second integration time is used.

(d) Only one scan of the search integrators is completed.

(e) Inputs signal and noise are both Gaussian and occupy the band of 1000 to 2500 cps."

3. Change Figure 2 referred to in 3.3.1.1.3(d) to have an abscissa of "TARGET RANGE RATE" instead of "TARGET SPEED".

B. Suggested Improvements

1. The sampling rate, 8300 samples per second, employed in the PADLOC processor provides correlation beams with theoretical processing gain sufficient to provide performance equivalent to the -11 db input signal-to-noise specification mentioned in paragraph 3.3.1.2.2.(b) when the target is exactly on one of the correlation beams. When the target is midway between two of the correlation beams, the available signal-to-noise ratio is down 4.6 db and there are two beams in which there is equal opportunity for detection. These 4.6 db holes in the correlator bearing dependence result in processing gain degradation of 2 db when averaged over azimuth. This situation is not materially improved unless the sampling rate and number of correlators is doubled.

2. The sum and difference scanner is a matched display as long as signals are observed in a noise background. Range samples are not independent when the 32 ms and 128 ms pulses are used and the background is reverberation if the sampling period is 7.4 ms. Clutter will be distributed along a given bearing as triplets in range with the 32 ms pulse and as septets in

range with the 128 ms pulse. If the sampling rate is matched to the reverberation bandwidth, the noise limited clutter appearance will be similar to the reverberation clutter appearance. The displayed target will extend 1-3 bins in range at beam aspect and 3-30 bins in range at bow aspect. Target orientation will beeasily discernible for 32 ms pulses and 4 ms pulses. Sampling periods of 22.2 ms for the 32 ms pulse and 50 ms for the 128 ms pulse appear suitable for the display matching. These sampling rates provide an excessively large range interval on the display (3900 and 8600 yards). A compromise must be made between the clutter behavior and the require displayed target size.

C. Need for Further Investigation

1. The behavior of the CW statistics of the wave period as it relates to the performance of the WPP and the DD has not been completed at this time. This analysis also can be easily extended to provide the statistics necessary to determine the complete ROC for the FM WPP performance. Simulation of the WPP processor by digital computer is the most efficient way to determine the overall behavior of the system as a function of doppler shift and input signal-to-noise ratio.

V. DISCUSSION: Signal Processing

A. INTRODUCTION

This discussion presents a brief description of each of the signal processors to be employed in the PAIR system and an estimate of the limiting values of input signal-to-noise ratios which will allow 50% detectability with specified display clutter. The performance specifications should be relaxed somewhat, 1 to 2 db perhaps, from the theoretical limits.

The processors included in this study are listed:

1. The Active Processors

   a. The Wave Period Processor

   b. The Audio Channel

   c. The Sum and Difference Scanner

2. The Passive Processor

   a. PADLOC

      (1) Search

      (2) Track

The statistical behavior of the CW wave period in the presence of reverberation and noise is not available at this time. It is to be simulated and performance of the wave period processor with CW input and the performance of the doppler discriminator will be described as soon as the results are available.

The block diagram of the receiver is included for convenience as Figure 1 under Task 11.

B. THE WAVE PERIOD PROCESSOR

1. Equivalent Operation

The description of the behavior of the wave period processor to be given here will be made in terms of "instantaneous" frequencies. The instantaneous frequency is one-half the reciprocal of the time between zero crossings. Its success as a detection system requires that noise alone produces a nearly uniform distribution of instantaneous frequencies over the band, while signal produces a nearly constant instantaneous frequency.

The operation of the wave period processor as its is to be implemented measures periods $T_i = T_o + \delta_i$ rather than instantaneous frequencies $f_i = f_o + \Delta_i$. In these expressions T_o is the central period in the receiver output, δ_i is a particular deviation from T_o, and T_i is the measured period of the ith period. The quantities of f_o, Δ_i, and f_i are the corresponding instantaneous frequencies. It is clear that if the instantaneous frequencies are uniformly distributed around f_o, that the periods are almost uniformly distributed also because

$$T_i = \frac{1}{f_o + \Delta_i} = \frac{1}{f_o} - \frac{\Delta_i}{f_o^2} + \frac{\Delta_i^2}{f_o^3} \cdot \cdot$$

$$= T_o - T_o^2 \Delta_i + T_o^3 \Delta_i^2 \cdot \cdot$$

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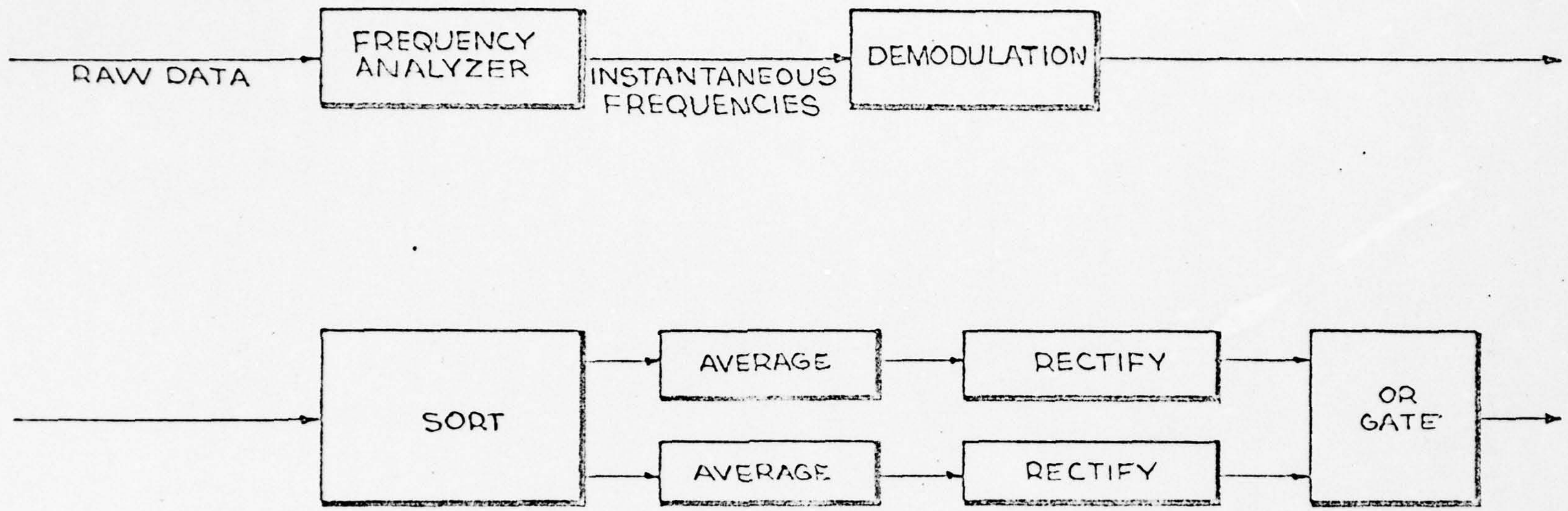

FIG. 1 - BLOCK DIAGRAM OF SIMULATION OF STATISTICAL WAVE PERIOD PROCESSOR

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deviates from linearity in Δ_i by less than 1% for $\Delta_{i_{max}} \sim 200$ c/s and $T_o = 1/20,000$ c/s. Hence with an error less than 1%,

$$T_i = T_o + \delta_i \cong T_o - T_o^2 \Delta_i \quad ,$$

and $\delta_i \cong - T_o^2 \Delta_i$ are almost equivalent representations of the samples processed by the wave period processor. This approximation becomes very poor as the data bandwidth to center frequency ratio increases.

The description of operation which follows is built around the response of the processor when processing a B = 400 c/s, T = 128 ms up slide centered at f_o = 20,000 c/s. The description is given in terms of instantaneous frequencies.

The statistical wave period processor can be simulated as shown in Figure 1. The system input data enters an instantaneous frequency analysis processor where the average time required for a complete cycle is measured. A length of data equal to the pulse length T divided by k, the number of frequency samples determined per pulse length, is used in determining the average period. The reciprocal of these times is transferred to the next stage. Typical instantaneous frequencies are shown in the upper part of Figure 2.

The instantaneous frequencies enter the demodulation phase where they are grouped into successive T second segments. Each segment is added term by term to a linear sequence varying from $- f_o + 200$ to $- f_o - 200$ in T second. (This sequence comes from the instantaneous frequencies of the signal.)

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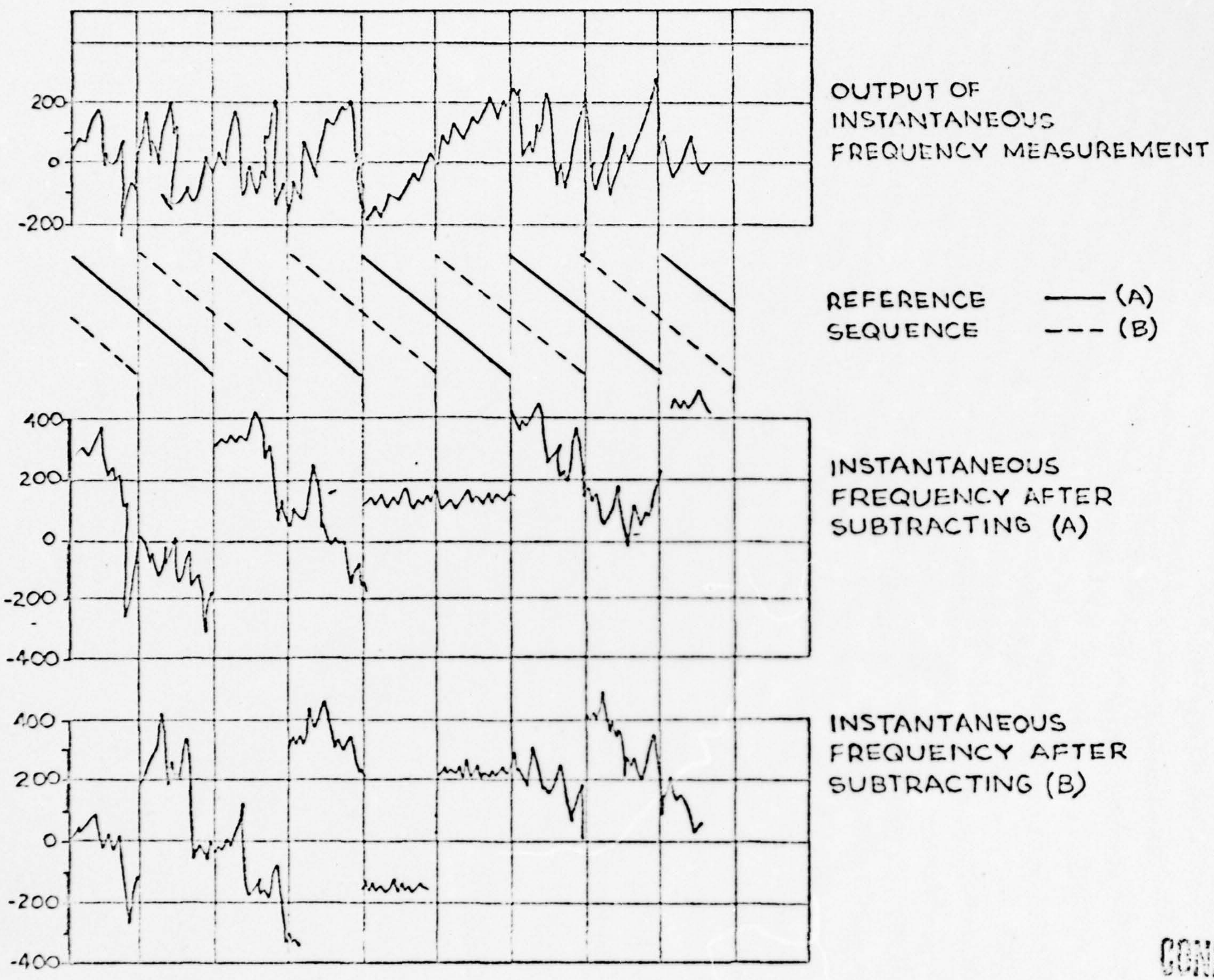

FIG. 2 - THE INSTANTANEOUS FREQUENCY BEHAVIOR

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The data are then sorted twice as follows: if the ith input sample to the sort stage is denoted by s_i then the ith sample of the first output channel is f_i, where

$$f_i = \begin{cases} +1 & -600 \le s_i \le -400 \\ & -200 \le s_i \le 0 \\ & +200 \le s_i \le +400 \\ & +600 \le s_i \le +800 \quad \text{etc.} \\ -1 & \text{otherwise} \end{cases}$$

and the ith sample of the second output channel is g_i, where

$$g_i = \begin{cases} +1 & -500 \le s_i \le -300 \\ & -100 \le s_i \le +100 \\ & +300 \le s_i \le +500 \quad \text{etc.} \\ -1 & \text{otherwise} \end{cases}$$

Each of the two outputs is averaged over T second and rectified. Then the two channels are "OR"ed together for the system output.

The processor was simulated as described above using as 0.5 second input 100 c/s FM sweeps and stationary Gaussian noise of nominally 100 cps bandwidth. See Figure 3a for a power density plot and Figure 3b for a cumulative power plot of the input noise. These signal characteristics were available in recorded sea data and served to check the theoretical behavior expected of the wave period processor. Figure 4 is the measured output cumulative probability function for noise alone plotted in the normalized coordinates of $P(x \ge T)$ versus $\frac{T - \bar{x}}{\sigma}$ where $\bar{x}$ is the mean of the output and σ is the standard deviation of the output. Figure 4 was extended theoretically as follows: Each channel of output of the sorter is a

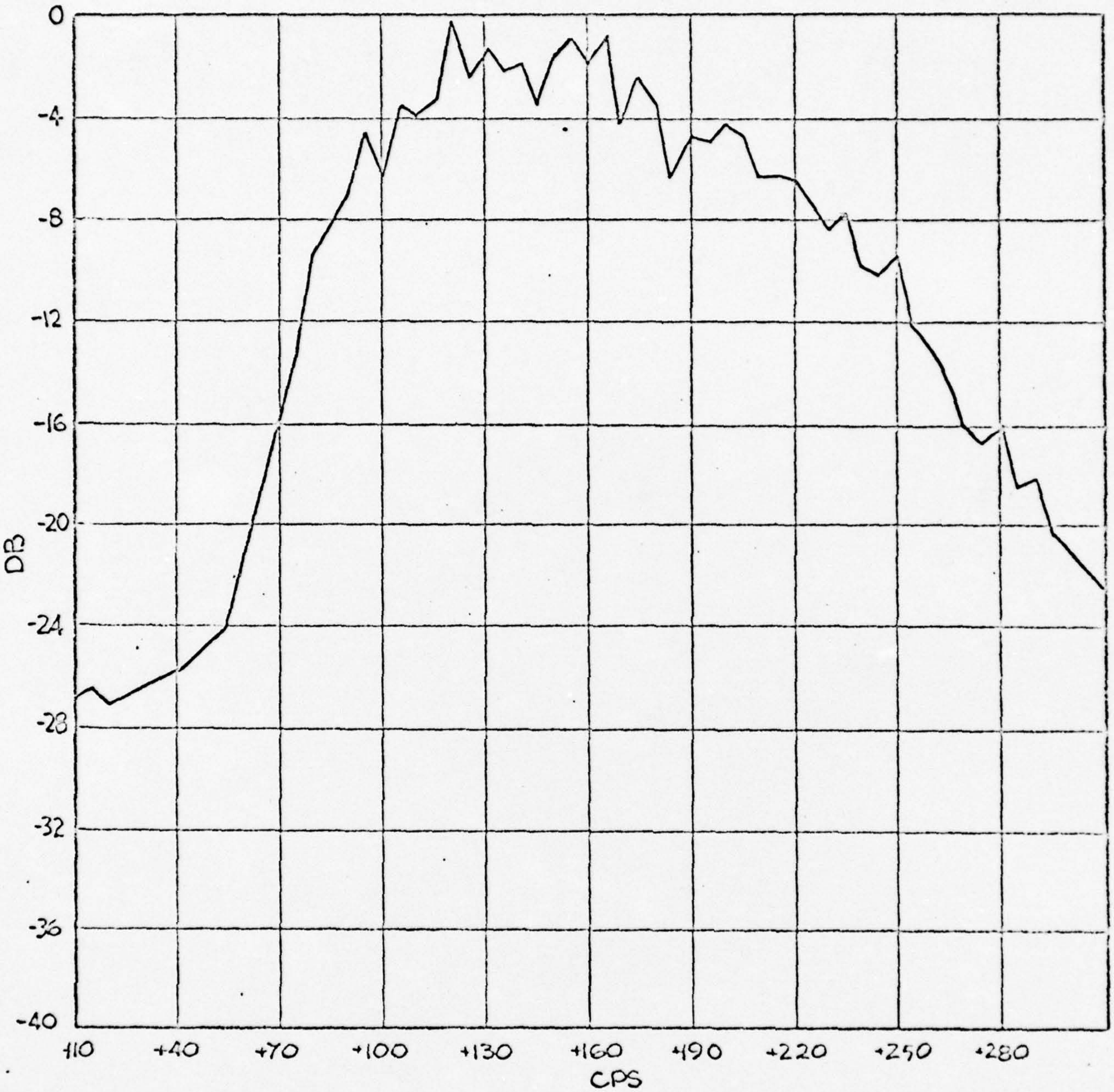

FIG. 3A-POWER DENSITY VS FREQUENCY INPUT NOISE

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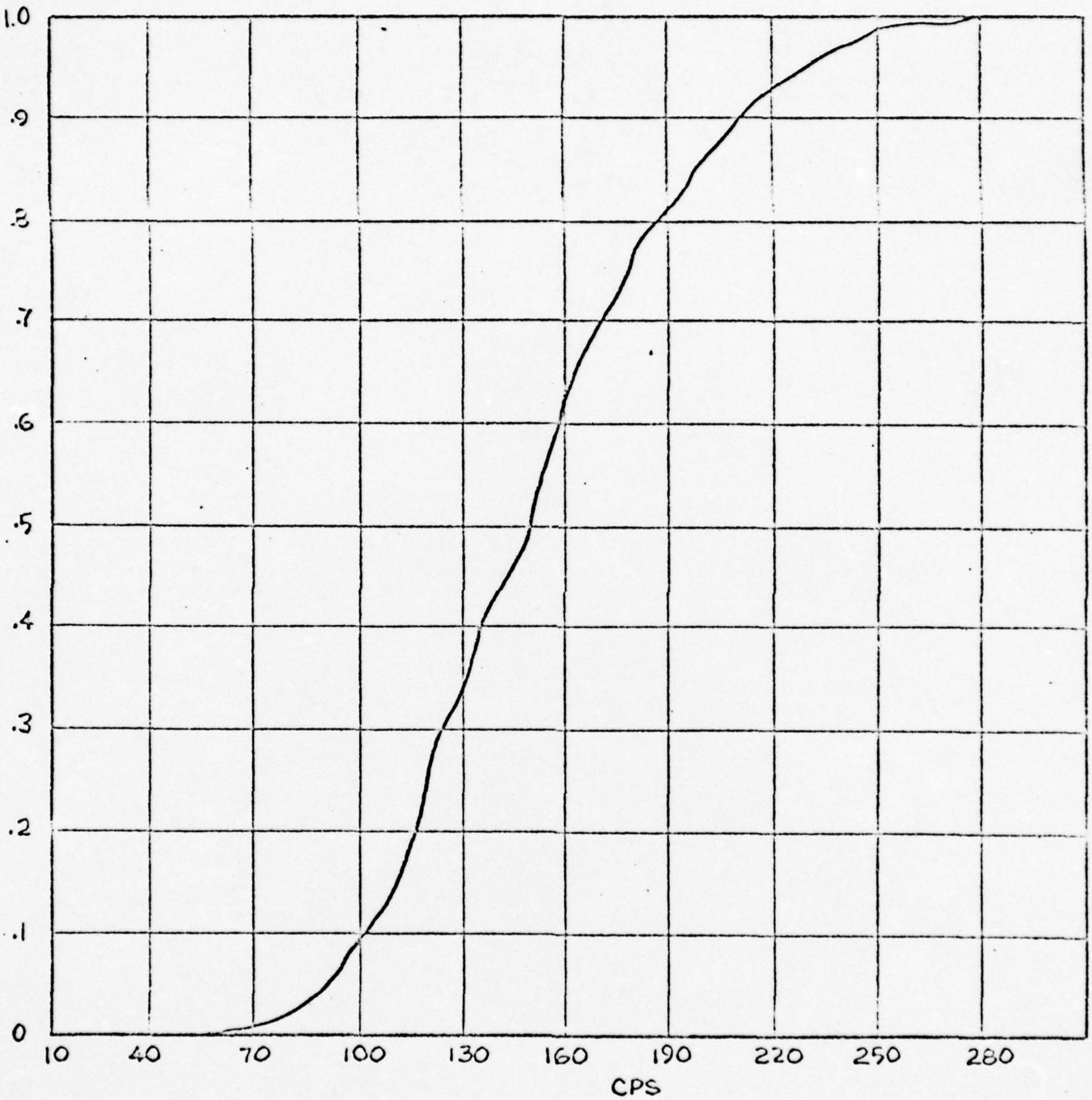

FIG. 3B CUMULATIVE POWER VS FREQUENCY INPUT NOISE

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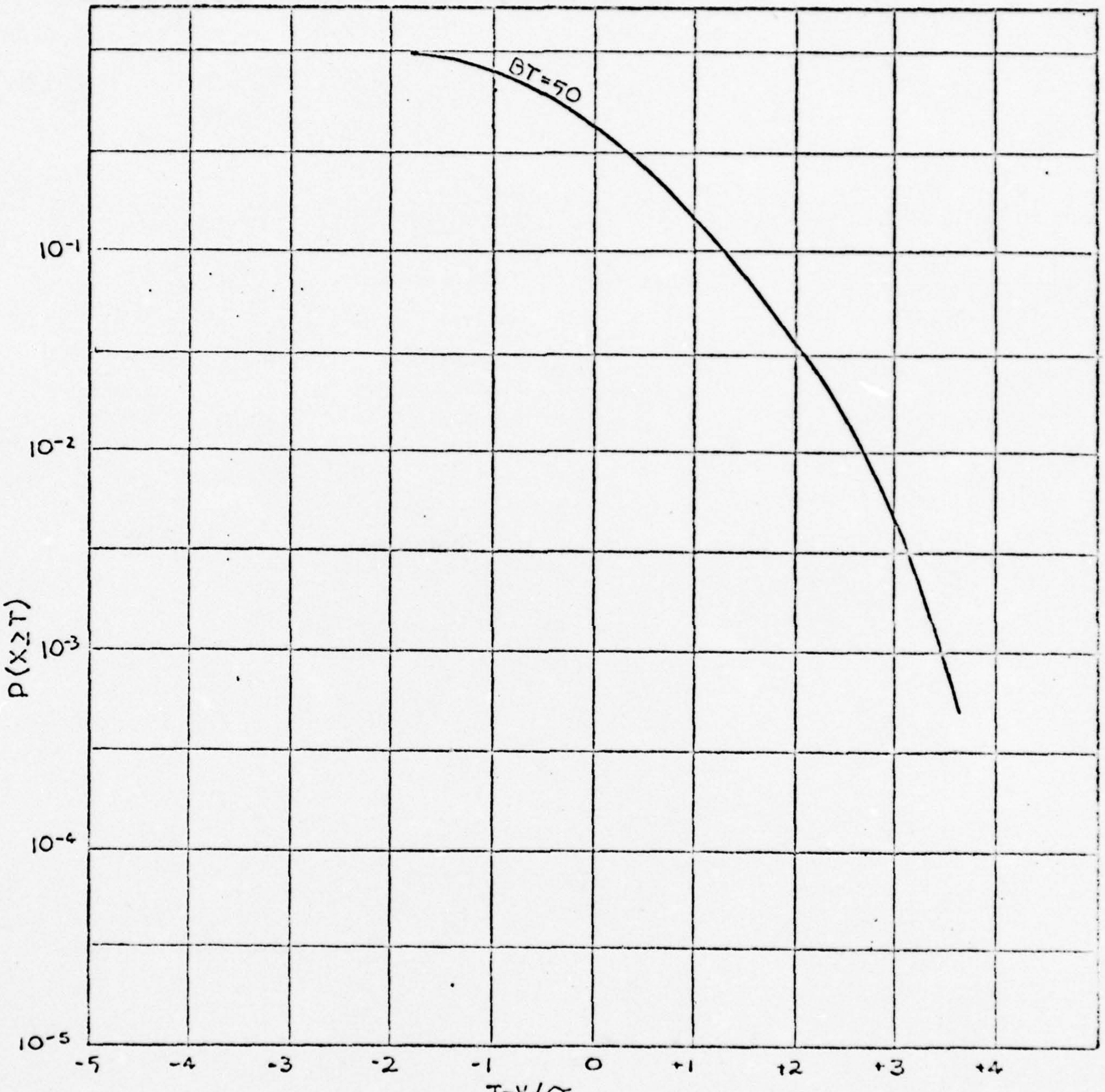

FIG. 4 - STATISTICAL ANALYSIS OF STATISTICAL WAVE PERIOD PROCESSOR OUTPUT WITH ONLY NOISE IN

sequence of Bernoulli trials with an even chance of +1 or -1. The output of the averager is a binomial distribution corresponding to 50 trials.

The figure of 50 independent samples was estimated from the fact that there were 100 independent samples in a 1/2 second signal of 100 cps bandwidth and it was assumed that 50 independent samples of the 100 were lost when the amplitude information was discarded in the frequency analyzer.

The simulation of the processor behavior for 0.5s, 100 c/s pulses is the same as the behavior for 128 ms, 400 c/s pulses because both pulse forms have a BT product of nearly 50. Figure 5 shows the probability of clutter as a function of $\frac{T - \bar{x}}{-\sigma}$ for BT = 50 and for 10 and 20 trials as well. The 28 ms, 400 c/s pulse corresponds to 12.5 trials, but from Figure 5 little difference can be seen between the plots for different values of n.

It has been shown* that if the input and output of the "OR" gate are compared, the output will have a higher mean and a slightly changed standard deviation. It was assumed that the effect of the "OR" process on the standard deviation was negligible. The mean of the theoretical curve was modified so as to yield the best agreement between it and the experimental cumulative probability curve. This agreement is good in the range of overlap.

Signals were added to the noise at input signal-to-noise ratios of -6 db, -3 db, 0 db, +6 db, +12 db, and +∞ for BT = 50 and 12.5 The output signal-to-noise ratios are plotted as a function of input signal-to-noise ratio in Figure 6. It should be emphasized that input signal-to-noise ratios are average to average ratios while the output signal-to-noise

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* Technical Memorandum, "The Effect of OR Gating in the AN/SQS-26, XN-2, dated September, 1963." TRACOR Document Number 63-235-U, Contract NObsr-89265.

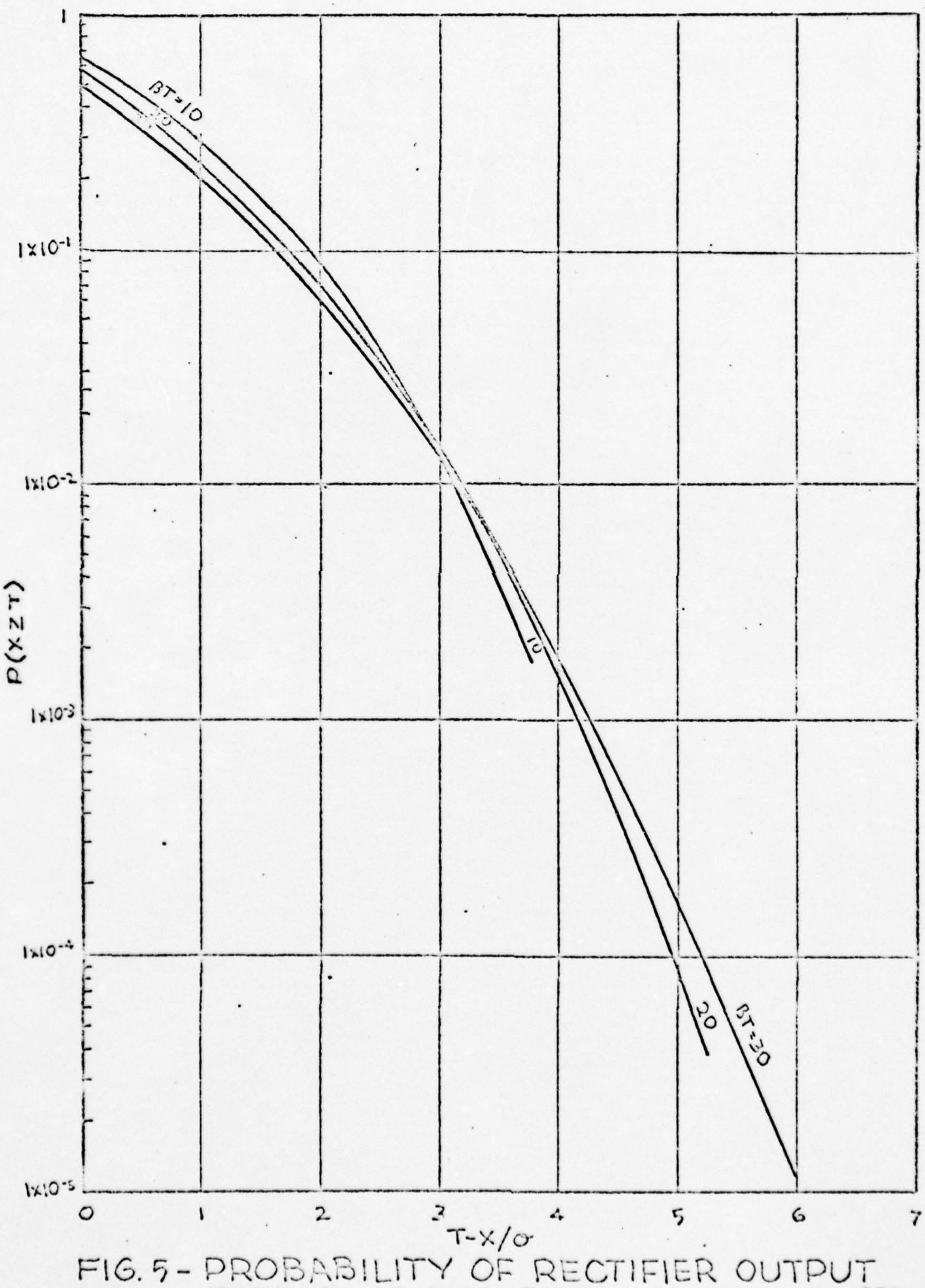

FIG. 5 - PROBABILITY OF RECTIFIER OUTPUT EXCEEDING A THRESHOLD FOR A GIVEN THRESHOLD

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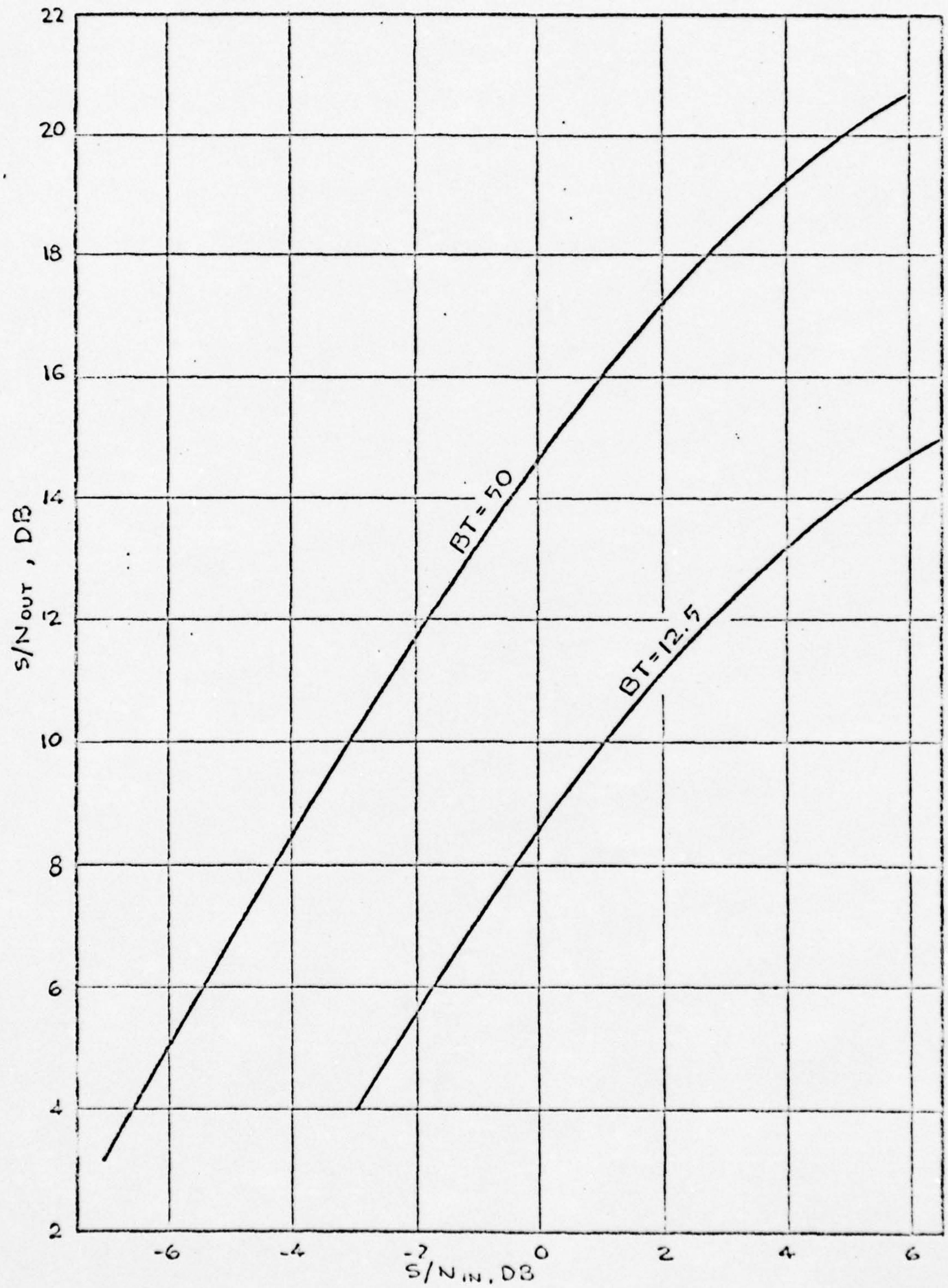

FIG. 6 - PROCESSING GAIN FOR STATISTICAL WAVE PERIOD PROCESSOR

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ratios are peak-to-average ratios. The upper curve is asymptotic to 21.8 db at large signal-to-noise ratios and approaches a slope of two for small signal-to-noise ratios. The lower is asymptotic to 15.2 db. Scaling to other BT product is accomplished by a vertical shift determined by the variation of 10 log BT.

Figure 7 is a detection nomograph prepared from the probability of clutter curve (Figure 5) and Figure 6. The only transformation in graphical form is the expressing of threshold $\frac{T - \overline{x}}{\sigma}$ in decibels and plotting the two curves with the db threshold scale in coincidence with the output signal-to-noise ratio curve on the processing gain curve. One chooses the independent sample clutter probabilty at which he wishes to work, draws a vertical line to the clutter probability curve, reads the threshold at which he must operate in db, draws a horizontal line to the processing gain curve corresponding to the signal BT product. From this intersection a vertical line is drawn to the input signal-to-noise ratio curve. The value read there is the processor input signal-to-noise ratio which will allow a detection probability of 0.5.

2. The PAIR Display

As it is presently specified, the PAIR active display will be arranged so that independent events can be displayed on 48 beams, each of which will have 48 discrete range increments, independent of the actual total range displayed. Marks will be displayed radially, in PPI format, with sufficient capacity to allow for the presentation of a 5-ping history. Matching of the display to the receiver data rate for each range scale and each pulse duration will be achieved by a serial OR process, specifically by

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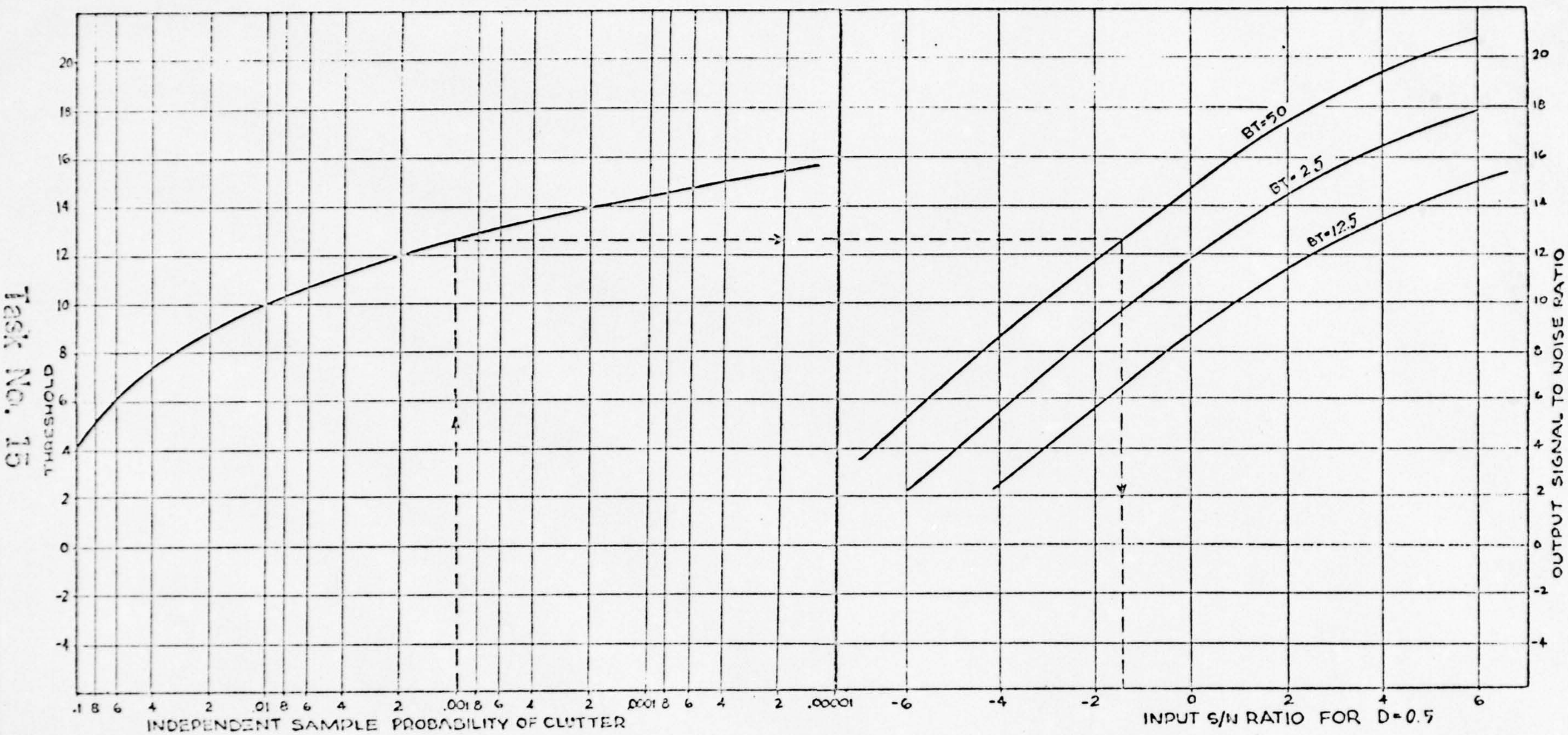

FIG. 7- WPP PROCESSOR DETECTOR NOMOGRAPH

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a peak detector. For a single echo ranging cycle, there will be about 2300 opportunities to mark on the display. If we wish to limit the average number of marks per echo ranging cycle to n, then the basic marking probability, p, per display bin needs to be

$$p = \frac{n}{2300} .$$

For the special case of 5 marks per echo ranging cycle, $p \approx 2.2 \times 10^{-3}$.

As mentioned above, the wave period processor has two parallel output channels, which are OR-ed to give a single output channel. At the low marking probabilities under consideration here, the marking probability from a single channel, p_1, is, therefore, given by

$$p_1 \approx \frac{p}{2}$$

which is approximately 1.1×10^{-3} per bin per channel.

Consider now the case of a 128 ms linear FM slide transmission with a 400 cps bandwidth. Since the range resolution of the wave period processor is determined by the pulse duration, an independent range sample covers approximately 0.105 kyd in range. The range increment, ΔR, which must be contained in each range bin of the display as a function of each range scale of interest here is shown in Table I. Also shown are the number of independent range samples which must be serially OR-ed in order to match the receiver output to the display. n is the ratio of the range increment to the length of an independent range sample.

TABLE I

Number (n) of Independent Samples Serially OR-ed Into a Single Range Bin for 128 ms and 32 ms 400 c/s FM Sweeps

Range Scale (kyd)	Increment (kyd)	n(128 ms)	n(32 ms)
32	0.667	6.35	25.4
16	0.333	3.17	12.7
8	0.167	1.59	6.3
4	0.084	.80	3.17
2	0.042	.40	1.59

The length of an independent range sample when using the 32 ms pulse is 0.0262 kyd. The values of n in the column labeled 128 ms are computed with the ratio $\Delta R/0.105$; those in the column labeled 32 ms are computed with the ratio $\Delta R/0.0262$.

When the probability of marking in a single range display interval is $p_1 = 1.1 \times 10^{-3}$, the probability P of marking by a single independent range sample can be computed using the expression,

$$p_1 = 1 - (1 - P)^n .$$

$(1 - P)$ is the probability that a single independent range sample will not exceed the threshold; $(1 - P)^n$ is the probability that none of n samples will exceed the threshold; the complement of this probability is p_1, that at least one of the n samples will exceed the threshold and mark.

For the small marking probabilities P involved, the parenthesis can be expanded so that to a very good approximation,

$$P = \frac{p_1}{n} = \frac{1.1 \times 10^{-3}}{n}$$

is the single independent sample probability of exceeding the threshold. The values of P are given in Table II for the combinations of pulse length and range scales to be employed.

TABLE II

Probability that a Single Noise Sample Will Exceed the Threshold

Range (kyd)	128 ms	32 ms
32	1.71×10^{-4}	4.3×10^{-5}
16	3.5×10^{-4}	8.6×10^{-5}
8	6.9×10^{-4}	1.73×10^{-4}
4	1.1×10^{-3}	3.5×10^{-4}
2	1.1×10^{-3}	6.9×10^{-4}

3. The Required Input Signal-to-Noise Ratio

The probabilities of marking in a single range sample and the curves presented in section entitled, "Equivalent Operation" (B.1) can be used to estimate the average signal power to average noise power ratio required at the input of the wave period processor to provide a detection probability of 0.5 with the specified noise marking density.

To accomplish this, one enters Figure 7 with the probability of marking from Table II to determine the threshold setting required to provide the required marking density. This threshold T is in units of the noise σ relative to the mean. A signal plus noise whose mean, expressed in uits of noise σ is higher than the noise mean by T will exceed the threshold 50% of the time, hence will mark or be detected 50% of the time. Hence $10 \log T = (S/N)_{out}$ is the required peak-signal-to-average-noise ratio at the output of the wave period processor needed to provide the 50% detection probability.

One then enters the processing gain plot in Figure 7 with $(S/N)_{out}$ to determine the corresponding processor input signal-to-noise (average-to-average) ratio. The values for 128 ms, 400 c/s sweep signals are read from the curve marked BT = 50; the values for 32 ms, 400 c/s sweep signals are read from the curve marked BT = 12.5.

The results obtained by carrying out this process for each range scale and each pulse form are shown in Table III. These results are plotted in Figures 8(a) and 8(b).

TABLE III

Average Signal to Average Noise Ratio Required at the Input to the Wave Period Processor for 5 Background Events Per Display Cycle to Provide a Detection Probability of 0.5

Range Scale 32 (kyd)	$(S/N)_{in}$ (128 ms)	$(S/N)_{in}$ (32 ms)
32 (kyd)	-0.6 db	6 db
16	-0.8	5.5
8	-1.2	4.7
4	-1.6	4.0
2	-1.9	3.5

The same performance can be expected from the CW pulses for high Doppler targets if the reverberation band is "notched" out or in a noise limited condition. The low doppler target echo falling within the reverberation band is a much worse situation; this condition of observation is to be avoided by using the FM sweep signal.

The wave period processor is not implemented in this way for CW operation. The notch is built into the processor. The detection probability depends upon the distortion of the reverberation wave period statistics for CW. An independent determination of these statistics is not available at this time.

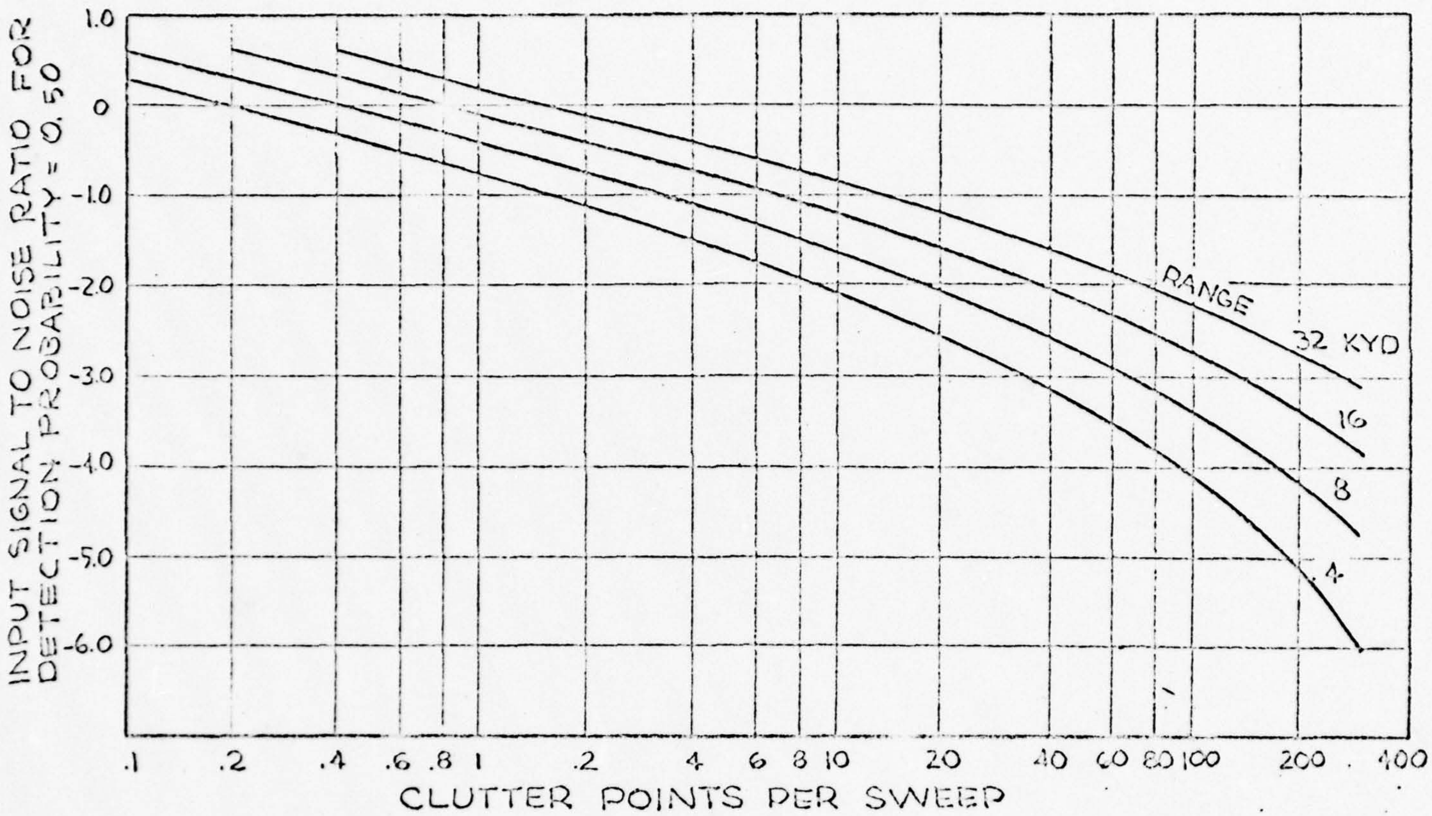

FIG. 8A- DETECTION PERFORMANCE : ACTIVE SYSTEM, 128 MS 400 C/S SWEEP, WPP

TSK 15

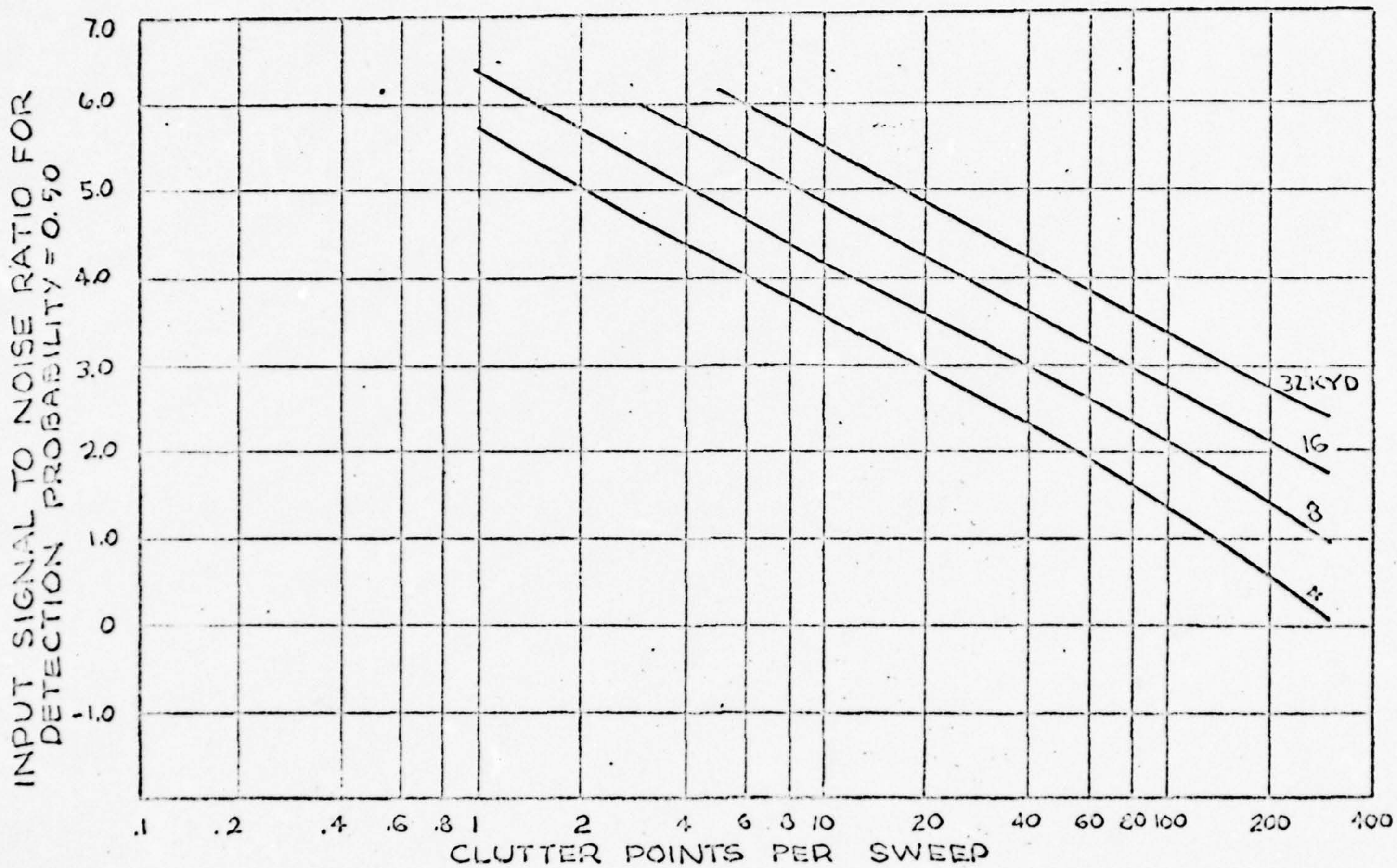

FIG. 8B- DETECTION PERFORMANCE: ACTIVE SYSTEM,
32 MS 400 C/S SWEEP, WPP

4. Comparison of Processors

The wave period processor, the detector averager, and the linear correlator detection performances are compared in Figure 9. The processors are compared at the same clutter rate. This type of comparison takes proper account of the processor output bandwidth, the output statistics, and the available processing gain.

Compared on this basis the wave period processor requires a larger input signal-to-noise ratio than the other processors. Its primary advantage is that it is automatically normalized so that it overcomes the main difficulty encountered with the detector averager. This advantage is undoubtedly responsible for its superiority to the detector averager in field tests. While there are good indications that the linear correlator can be normalized in a reliable manner, equipment for doing this on a real time basis has not been constructed.

B. PAIR PASSIVE PROCESSOR

1. The System Description

The passive system utilizes the two hydrophone arrays which are separated on the hull by 60 ft. A total of 24 beams are formed with each transducer utilizing conventional beamforming techniques. The outputs of corresponding beams (those with the same bearing β) in the two arrays are clipped and cross correlated with a number of delays centered around the delay Δ_o,

$$\Delta_o = \frac{60 \text{ Cos } \beta}{C} ,$$

corresponding to the delay between array centers for the bearing β. C is the velocity of sound.

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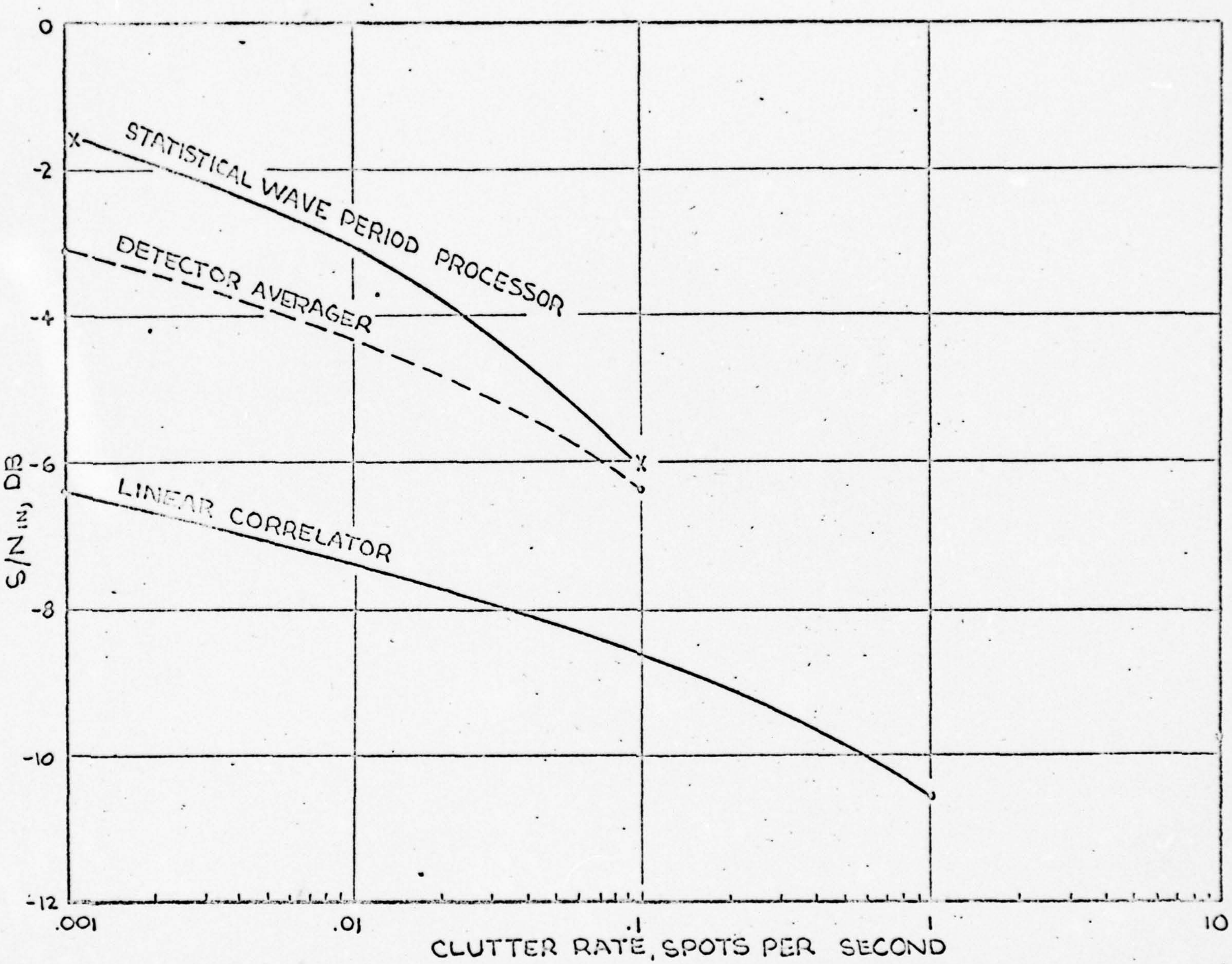

FIG. 9-CLUTTER RATE FOR 50% PROBABILITY OF DETECTION FOR A GIVEN S/N_{IN}

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The response of a single frequency correlator of this type is shown in Figure 10. The output is maximum when the delay Δ employed in the correlation is equal to the difference in signal arrival time Δ_T at the two arrays from the target. The output is zero when the value of Δ is one quarter of a wave period, $\lambda/4C$, from Δ_T. The processing gain is down 3 db from its maximum value when the value of $\Delta - \Delta_T$ is $0.3\lambda/4C$ or about 0.075 wave periods.

The clipper cross correlator employed in passive search is a relatively wide band device, covering the band from 1.0 kc/s to 2.5 kc/s. If the passive signals in this band are prewhitened then the average loss across the band because of use of a value of Δ differing from Δ_T is determined to a good approximation by the loss at the band center $f_c = 1.75$ kc/s.

The sampling frequency is 8.3 kc/s so that the center frequency issampled 4.75 times per cycle. It follows that only delays spaced at 0.21 of the center frequency wave period are available for the correlation process. This spacing guaranties that the ideal delay required for a target on a given bearing will never differ from an available correlator delay by more than 1/2(0.21)= 0.105 center-frequency, wave periods. Figure 10 shows that with this delay error the clipper correlator processing gain in 4.5 db below its optimum value. Furthermore the degradation is more than 3 db for 25% of the azimuths to be surveyed. The sample rate would have to be raised to approximately 11.7 kc/s to maintain the processing gain within 3 db of the optimum value at all azimuths. Doubling the sampling rate is required to keep the loss in processing gain less than 2 db at all azimuths.

The angular spacing 2δ between correlation beam centers is related to the array beam bearing θ by the expression

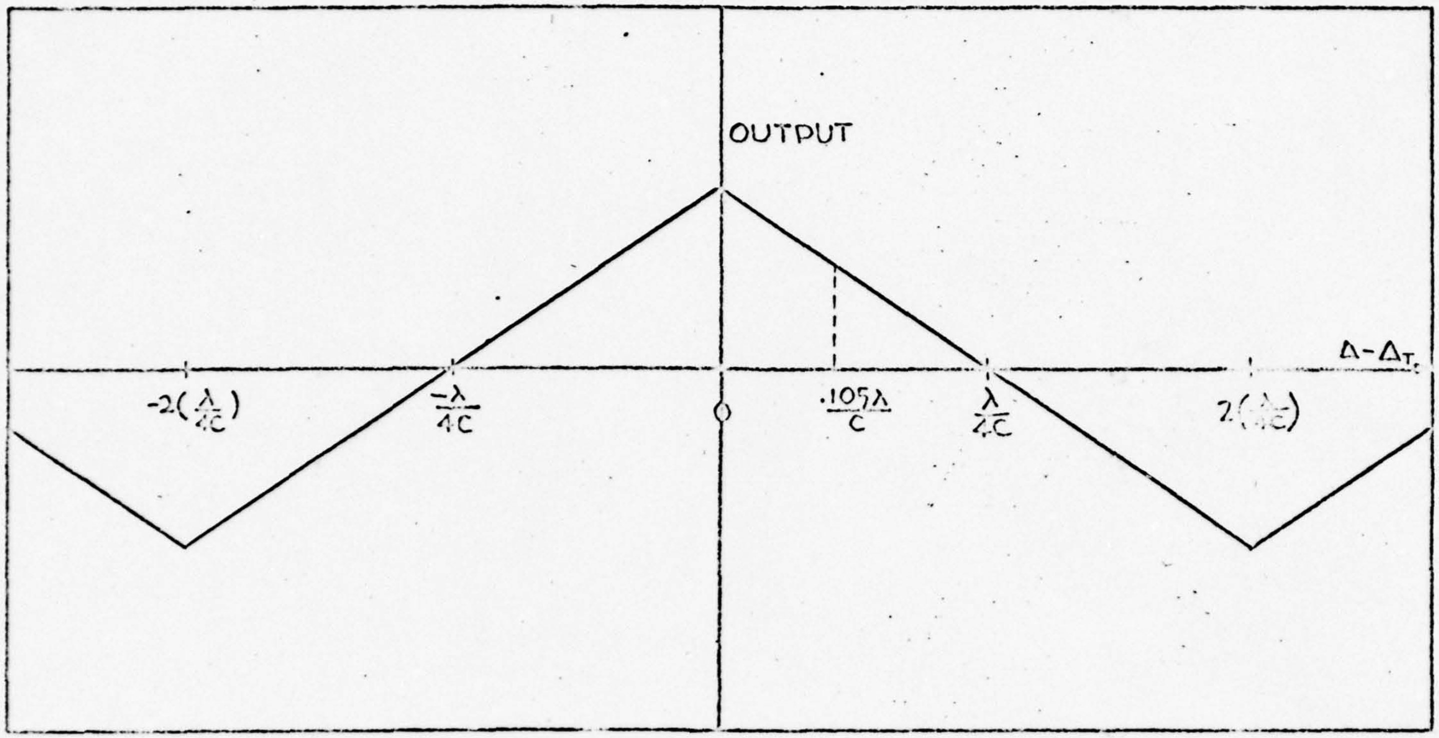

FIG. 10 - RESPONSE OF A SINGLE FREQUENCY CLIPPED CROSS CORRELATOR

$$\cos\beta - \cos[\beta + \delta] = \frac{0.105\ (5000)}{60\ (1750)} = 0.0050.$$

This reduces to

$$2\delta \cong \frac{0.75}{\sin\ \beta}$$

when δ is expressed in degrees. The quantity 2δ is the separation between adjacent correlation beam centers. Values of 2δ are listed in Table IV for several array beam bearing values. The number of correlation beams per 15° array beam is given as well.

TABLE IV

Correlation Beamwidths and No. of Beams Per Array Beam

Bearing, β (degrees)	Beam Separation (degrees)	No. of Beams
7.5	4.4°	3
22.5	1.5	10
37.5	0.94	16
52.5	0.72	21
67.5	0.68	22
82.5	0.59	25

The total number of integrator channels is four times the sum of the column headed "Number of Beams". This is in agreement with the number given in the original specifications. This number of integrators provides a processing gain 2 db below optimum averaged over all azimuths with the worst degradation (4.5 db down) midway between correlation beam centers.

2. The Detection Performance

Detection performance of the PAIR system in the passive mode can be predicted using the same techniques utilized in the active system. The first step is the construction of the curves showing probability that a

given noise sample at the processor output will exceed a threshold $(T - \bar{X})/\sigma$. The second is the determination of the relationship between processor output and input signal-to-noise ratio.

The clutter statistics are easily obtained because large BT products are involved and the output statistics are guaranteed Gaussian by the central limit theorem. The left portion of the nomograph in Figure 11 is a plot of the clutter probability as a function of $(T - \bar{X})/\sigma$ expressed in decibels.

The relationship between the processor output and input signal-to-noise ratios for the clipper cross correlator is shown in the right portion of the nomograph. These curves, corresponding to different bandwidths and averaging times are determined by the well known expression given by Faran and Hills for the clipper cross correlator,

$$(S/N)_o = 1.725 \, BT \, [\mathrm{Sin}^{-1} \frac{(S/N)_i}{1 + S/N_i}]^2 \quad .$$

Scaling for other BT products is accomplished by shifting the curves vertically according to the variation of

$$10 \log BT$$

from one curve to the next.

In order to determine the detection performance at a given clutter probability, one enters the left portion at the specified clutter probability, goes vertically to the clutter curve, then horizontally from this point to the curve having the operational BT product, then vertically down to the input signal-to-noise ratio required to provide 0.50 detection probability.

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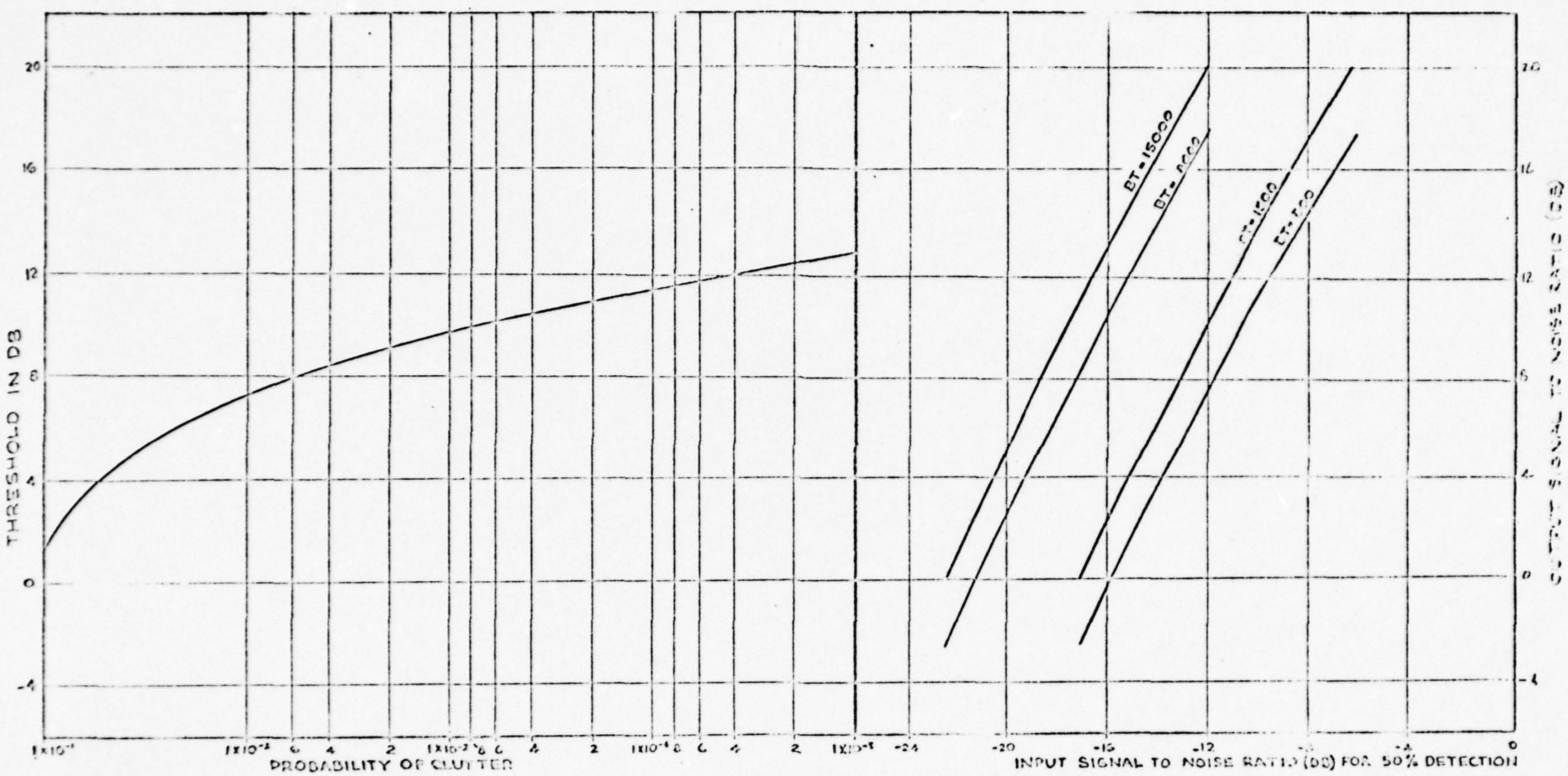

FIG. 11 - DETECTION NOMOGRAPH FOR THE PASSIVE CROSS CORRELATOR

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A result of this procedure is shown in Figure 12, where required input signal-to-noise ratio is plotted vertically as a function of clutter points per sweep across 400 integrators.

A similar performance curve has been plotted for the passive search model. For this mode the number of integrators per array beam varies with array beam bearing as shown in Table IV. The track function can be carried out with the 1.0 to 1.8 kc/s bandwidth or with the 1.0 to 2.5 kc/s bandwidth. The plot showing expected search performance will therefore depend upon array beam bearing (because the number of correlator beams depends upon array beam bearing) and the number of noise-alone threshold crossings allowed per unit time.

The number of independent samples per unit time is just the number n as given in Table IV. If $\dot{F}$ represents the clutter rate in total clutter points per second, then the probability of occurrence of a clutter point on a single independent sample is

$$P = \dot{F}/n ,$$

since an independent sample occurs in each channel each second. For each $\dot{F}$ to be plotted on the performance graph, P is computed as shown using the value of n from Table IV for the beam bearing under study. The left side of the graph in Figure 11 is entered with P. A vertical line is drawn to the clutter rate graph. From this intersection point a horizontal line is drawn to the processing gain curve corresponding to the BT product of the processor. From this intersection point a second vertical line to the input signal-to-noise ratio axis provides the processor input signal-to-noise ratio for 0.50 detection probability. The results of such a construction are shown

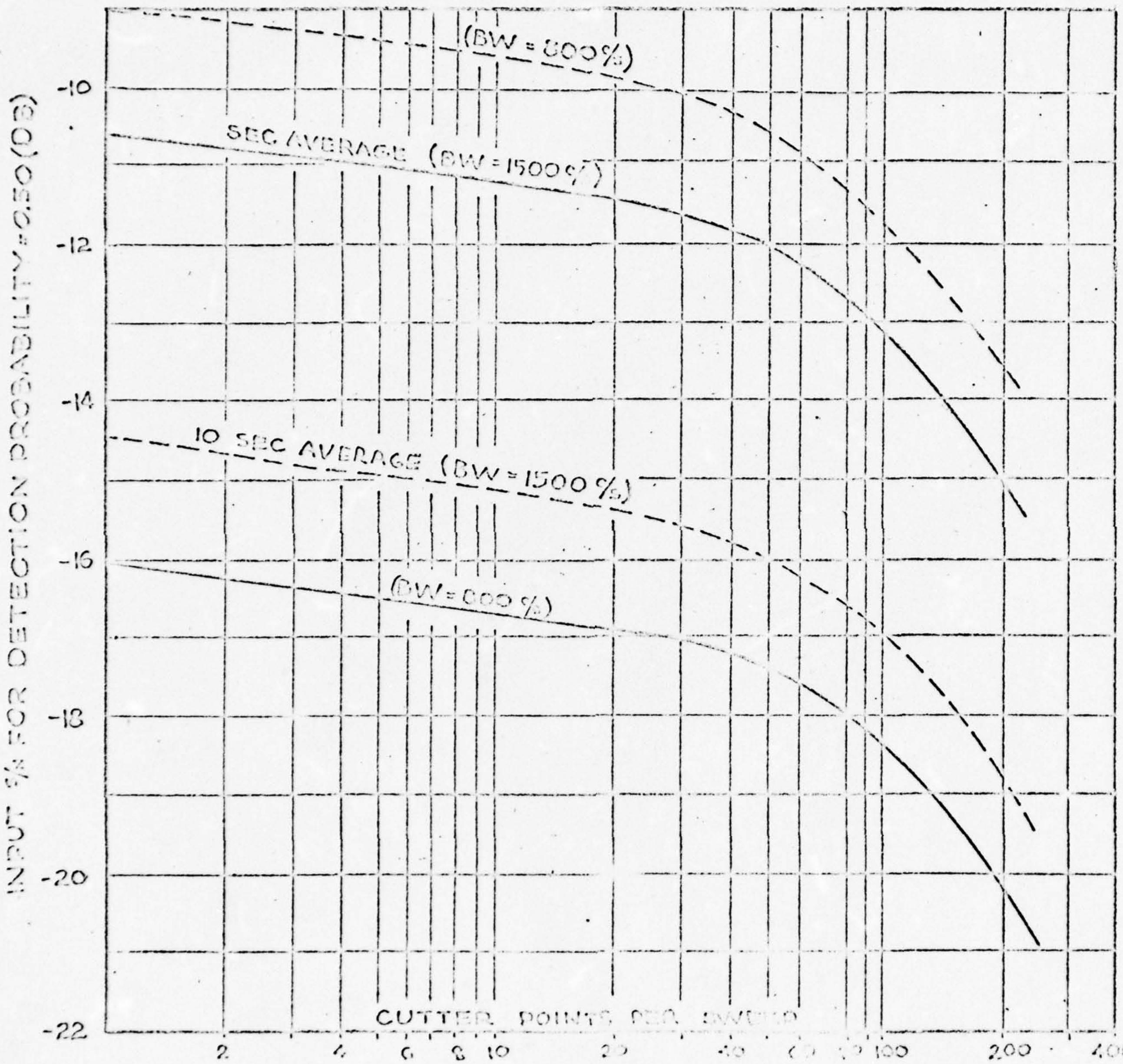

FIG. 12- DETECTION PERFORMANCE - PASSIVE SEARCH

in Figure 13. The resulting curves are rather shallow, 2-3 decades of clutter rate change being necessary to lower the input signal-to-noise ratio for 0.50 detection probability by 1 db.

B. THE SUM AND DIFFERENCE SCANNER

The scanner display has provision for displaying 48 resolved bearings and 240 resolved range increments. This is a total of 48 x 240 = 11,520 bins. At a particular range the fastest sampling rate (3.7 ms per bearing sweep) provides a new signal sample from each beam every 3.7 ms. The input bandwidth to the scanner is 470 c/s, which guarantees that independent samples of noise arrive on the average every 2.1 ms when a noise limited condition exists and every 4 ms when a 4 ms pulse is employed. It follows then that for this scanning rate and all others that each displayed sample will involve independent noise samples.

In order to keep the clutter to 5 events per display sweep, the probability p of clutter in a particular range bearing bin is

$$p_1 = \frac{5}{11,520} \cong 4.3 \times 10^{-4} .$$

If one enters the curves describing the statistics of steady signals in Gaussian noise described by Lawson and Uhlenbeck* and tabulated by Marcuum** the threshold setting necessary to maintain a single bin marking probability of $p_1 = 4.3 \times 10^{-4}$ in the absence of signal can be obtained.

The same curves provide the signal-to-noise ratio necessary to provide a single bin marking probability of 0.5 (50% detectability) with this same threshold setting. The value obtained is 9.1 db.

* J. L. Lawson and G. E. Uhlenbeck, Threshold Signals p. 51., McGraw Hill Book Company (1950)

** J. I. Marcuum, "Tables of Q-Functions" Project Rand Research Memorandum M-339, 15 January 1950. The Rand Corp. 1700 Main St., Santa Monica California, Astia Document AD 116551.

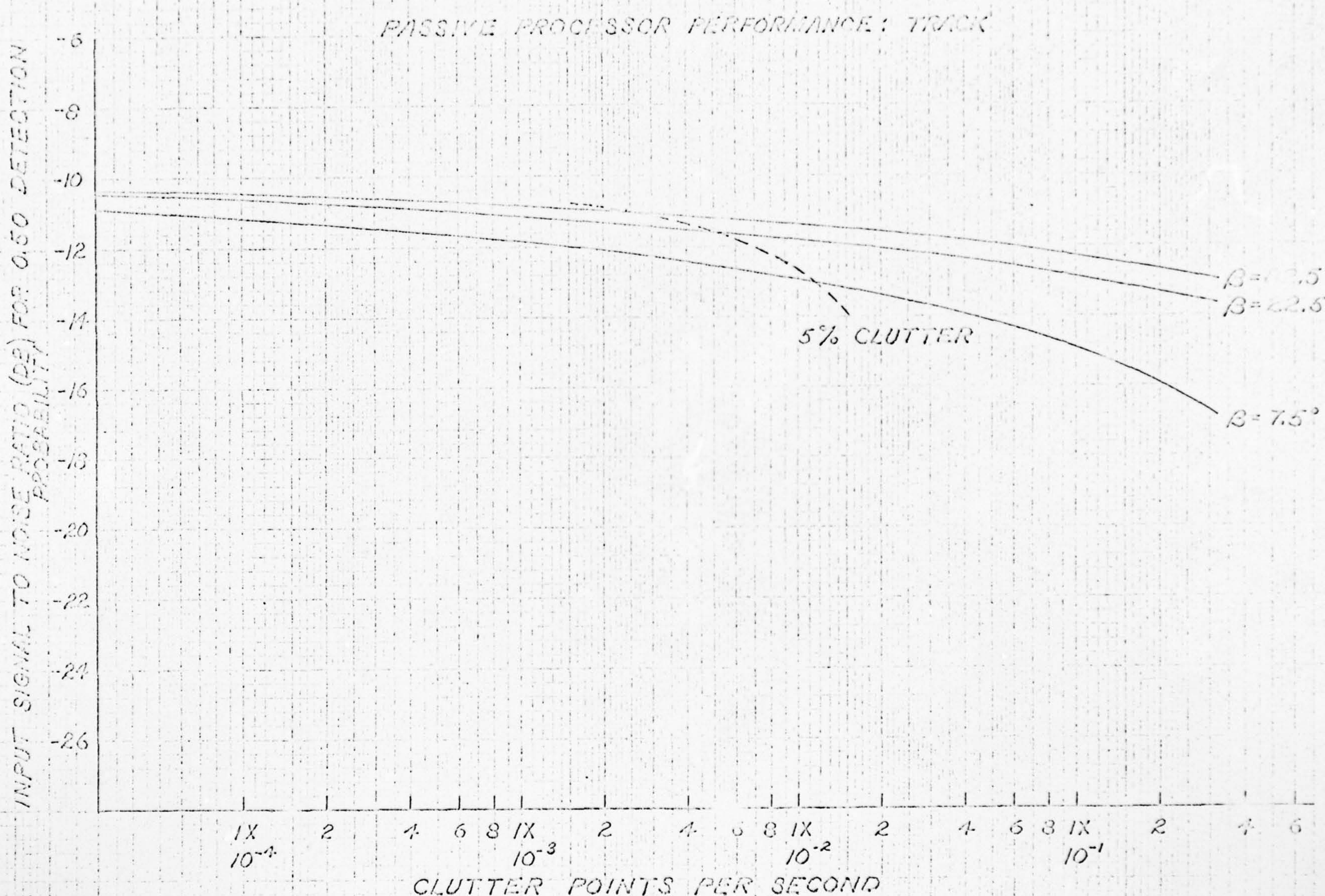

FIGURE 13
TASK 15

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The situation with longer pulse lengths (32 ms and 128 ms) is not different as far as the single bin marking probabilities are concerned. The theoretical single bin performance limit is useful for testing the processor behavior. The +9.1 db value of S/N is about 2 db lower than the value listed in the new specification.

The signals which can be employed to test the SDS are restricted in their minimum length because of the sampling period (3.7 ms) and the pass band (470 c/s). If a 4 ms pulse embedded in noise background is employed in the test the single bin marking situation will be exactly as described above. This pulse is suitable for test of this scanning rate.

When the pulse length is increased to 32 ms, the scanning period is increased to 7.4 ms. The noise samples are still independent if noise limiting occurs. When reverberation limiting occurs the noise bandwidth will be about 42 c/s, corresponding to an independent noise sample spacing of about 24 ms. Adjacent range bins on the same bearing are likely to mark in triplets if the 7.4 ms sampling period is utilized. This is an effect which will occur at sea under reverberation limiting conditions. To alleviate this difficulty the sampling period could be increased to 21.2 ms. The sampling period should not be made greater than this amount because to do so will reduce the probability that multi-marking will occur on a real target.

For testing this scale with the 7.4 ms sampling period an 8-10 ms pulse should be employed. If the pulse is longer there will be several marking opportunities while the signal is on. This increase in the number of opportunities will increase the probability that the equipment will exceed performance specified.

When the 128 ms pulse is employed, the time between independent noise samples is still about 2.2 ms. Under reverberation limited conditions the bandwidth of the background waveform will be approximately 20 c/s, corresponding to 50 ms between background independent sample times. With the 7.4 ms sample times and reverberation limiting there will be a high probability the 7 or more adjacent range bins on a single bearing will mark when one of them does. Testing this scale should be carried out with a test pulse slightly longer than the sampling time.

The above discussion has pointed out that this is a matched display when the background waveform is noise. The clutter is determined by independent sample behavior and target structure will be displayed 2 - 30 points in range depending upon aspect, pulse length, and sampling period. When reverberation limiting sets in the bandwidth is significantly decreased. For the 32 ms pulse clutter will appear in triplets and for the 128 ms pulse clutter will appear in septets along a single bearing. The display is therefore not matched to the waveform statistics under the conditions of reverberation limiting.

D. THE AUDIO CHANNEL

The detection performance in the audio channel is not essentially different from the performance with CW sonars except in one respect. The human listener is capable of behavior equivalent to tracking an FM slide of moderate width. Experiments* with 100 c/s FM sweeps with 150 ms duration centered at 800 c/s show that these pulses are detected with the same ROC performance as a CW of the same length. Extrapolation to wider sweeps is

* TRACOR Document 65- 184 - C "Summary Report for AN/BQS-6 Sonar Signal Processing Analysis", Contract NObsr 91349, May 14, 1965

probably not justifiable. The results of these experiments placed the required input signal-to-noise ratio for 50% detectability (listening clutter rate .001/sec) at +3 db when signals were embedded in uniform noise with 200 c/s bandwidth. Increasing the bandwidth provides more potential processing gain, but increasing the bandwidth reduces the listener's ability to achieve this gain. These two effects tend to compensate so that the corresponding expected S/N ratio for equivalent performance with 400 or 470 c/s bandwidth and 400 c/s sweep will not be lowered by as much as 3 db. The expected input S/N ratio is estimated to lie between 0 db and +3 db. This number will apply only when the background is maintained at a uniform level.

E. PROCESSOR PERFORMANCE AND TARGET DETECTION

Estimates of the capability of the active search system to detect a submarine can be made using the specified processor performance. Figure 14 shows estimates of the reverberation levels, the noise levels, the target echo levels for in-the-layer and below-the-layer targets. The signal-to-noise ratio necessary to detect the signal 50% of the time when only 100 clutter points appear per display sweep. This plot is the dashed curve just below the reverberation curve. It becomes horizontal at the appropriate sea noise level. These estimates indicate that below-the-layer targets can be detected ideally out to about 3000 yards. When the specified signal-to-noise ratios (+1 db on the 32 kyd range) is utilized the detection range is reduced somewhat below 2500 kyd.

In these plots a sea state 4 surface was assumed for producing surface reverberation. In these examples the target level falls below the reverberation level before noise limiting sets in for below-the-layer targets. The maximum detection ranges estimated are somewhat larger than those pre-

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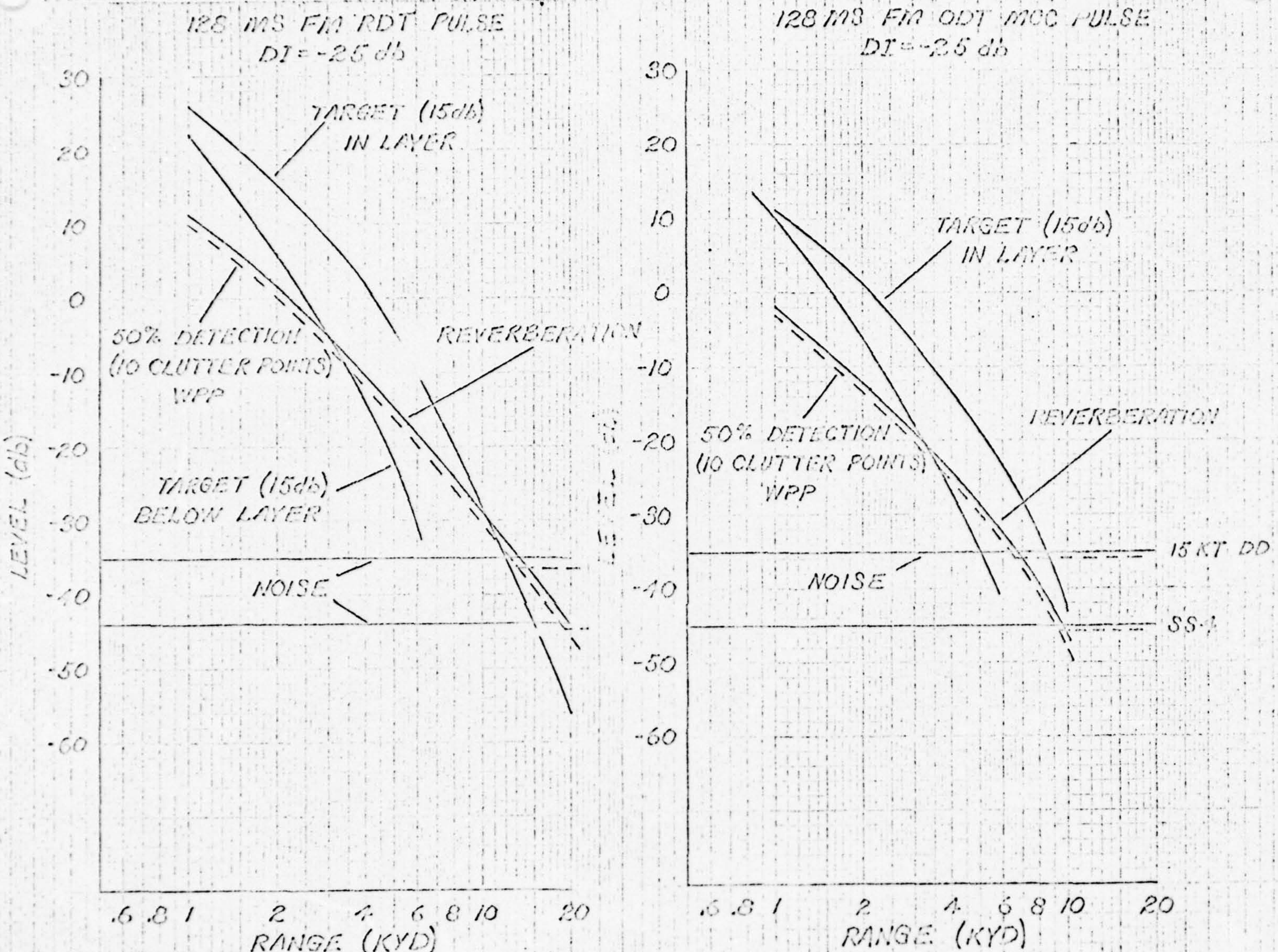

SINGLE PING PERFORMANCE AGAINST SUBMARINE

FIGURE 14
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sented in the Sperry report. This difference is caused by the difference in receiving directivity index used in these estimates. The reverberation directivity index will be a few db below the value used here. The discrimination against surface reverberation is not as good as against isotropic noise, in general. In addition the RDT mode introduces an asymmetry in the reverberation field. This effect has not been estimated but it should be included in the continued study of performance under a variety of operating conditions.

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I. TASK NUMBER: 16

II. TASK TITLE: EMEC Transmitter Portion

III. INVESTIGATOR(s): H. Klee and R. Klug

IV. CONCLUSIONS

A. Recommended Changes to the Specifications

1. Clarification of the "PAIR"---"TRAM" Interface

The PAIR requirement for the transmitter to supply enough electrical power to the transducer to produce a source level of 135 db ref μbar at one yard, requires simultaneous operation of both groups of TRAM amplifiers. If only one group of amplifiers is used to drive the complete transducer, the requirement for 135 db source level from one amplifier group would have the transmitter operating in a unreliable mode. (Refer to Part V). This should be considered in the PAIR TRAM interface.

B. Suggested Improvements

The amplifiers in the TRAM transmitter have a relatively high output impedance of about 2000 ohms. This high output impedance in comparison to a single transducer element value of 48 ohms ±10%, would make the amplifier appear to the load as a current source. To take advantage of this type drive, for an aid in obtaining velocity control, the 4 or 5 elements driven by a single amplifier should be connected in series. This change would require different output transformers from those now supplied in the TRAM transmitter. If transducer elements are individually grounded, another problem is imposed.

Power level control permitting reduction of power by as much as 30 db is highly recommended for use under some operating conditions. A manual transmit power level control can easily be incorporated into the

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existing automatic power level circuits, however, maximum reduction in source level at present is 7 db. Resistive swamping across the load could reduce this even further.

C. Need for Continued Investigation

Reference Task Number 28 - Harmonic content of the TRAM transmitted signal, in the region of 30 to 60 kc, is sufficient to interfere with a MK 44 torpedo's guidance system within a range of 1500 yards. Definite numbers are not available, however indications show that the MK 37 and MK 46 torpedoes would be even more suseptible to the radiated harmonics. If close tactical ranges are necessary, modified operational procedures or a transmitter modification will be needed. (Reference NOTS TP 2475.) Continued study is necessary

Further study is necessary to determine the degree of heating in the high voltage motor generators due to the higher duty cycle imposed by some modes of PAIR operation.

Further investigation is necessary in the area of velocity control of the transmitter/transducer complex. If a need for more velocity control is found, methods to achieve this goal will have to be determined.

Additional study of means for harmonic suppression of the transmitter output is necessary.

V. DISCUSSION

A. Safety Factor

Allowing a 30% safety factor and using 70% of the maximum transmitter power capabilities, assures that some reserve power remains to handle load mismatch. Figure 1 shows that a source level of 135 db ref μbar at one yard leaves ample reserve amplifier power when coupled to a 50% efficient transducer but that no reserve is left when coupled to a 30% efficient transducer.

C. Source Level

The TRAM modification provides for operation of sonar with only one group of amplifiers energized, one driving each 9 element stave. If the 30% safety margin is observed, the source level under these conditions will be limited to 134.5 db/μbar at one yard for a 50% efficient transducer and 132 db for a 30% efficient transducer.

D. Primary Power

The high voltage motor-generators are heavily loaded under some PAIR operating modes. The four generators can deliver approximatly 30 KW continuous, based on their efficiency and horsepower ratings of the drive motors. More power can be supplied for short duty cycles because of energy storage in their flywheels. This would supply the high voltage needs for the 135 db source with a 50% efficient transducer. The use of a 30% efficient transducer, or driving with one group of amplifiers only, will cause generator heating. The generators should be worst case tested to insure system reliability.

E. Power Level Control

The TRAM transmitter package now has an automatic power level control that can reduce the output power by 7 db in 4 steps. At present this control is actuated when the operating mode is such that the duty cycle limitation of the transmitter will be exceeded. The controlling relays could easily be manually controlled from the console for power reduction during very high reverberation conditions. A minimum output power of 200 watts per amplifier must be observed or a distorted output will result.

F. Harmonics in the Output

The output circuit of the amplifiers is tuned with a Q of 2.8, providing a bandwidth of 1.8 kilohertz at the -3 db points (centered at 5 kilohertz). This low Q allows harmonics to appear in the output. The harmonic content of the AN/SQS-23 output pulse was analyzed by NOTS in May of 1960 (NOTS-TP 2475). The test SQS-23 had a source level of 138.6 db ref 1 μbar at one yard. The sixth harmonic (30 kilohertz) was down 40.7 db and the twelfth harmonic (60 kilohertz) was down 61.7 db. NOTS determined that these levels would interfere with a MK 44 torpedo within a range of 1600 yards. The TRAM transmitter package will provide a lower source level of 135 db which would reduce the interfering range to 1500 yards. Available information indicates that the MK 37 and MK 46 torpedoes would be affected at an even longer range.

G. Velocity Control

There has been no known attempt to achieve any degree of velocity control on the AN/SQS-23 TRAM transmitter modification. There are no tuning elements in the amplifier/transducer interface and the output impedance of the transmitters is quite high (approximately 2000 Ω). The type amplifier being used normally has a high output impedance, therefore modification, short of complete redesign, is not practical. Tuning controls or elements could be used between the transmitters and the transducers. However addition of more high level components could reduce the system reliability. This problem needs further detailed study.

Source Level db//μbar/1 yd	12 Staves DI=23.9db BW=9.3° Tot. P_E (KW)	13 Staves DI=24.2db BW=8.7° Tot. P_E (KW)	14 Staves DI=24.4db BW=8.2° Tot. P_E (KW)	15 Staves DI=24.6db BW=7.8° Tot. P_E (KW)	16 Staves DI=24.8db BW=7 ° Tot. P_E (KW)	17 Staves DI=25.0db BW=7.2° Tot. P_E (KW)
134	14.2	13.2	12.6	12.1	11.5	11.0
135	17.8	16.7	15.9	15.2	14.5	13.9
136	22.5	21.0	20.0	19.1	18.3	17.5
137	28.3	26.4	25.2	24.1	23.0	22.0
138	35.6	33.2	31.7	30.3	28.9	27.6

Transducer efficiency 50%

Table 1

Alternating Current Power Required to Drive the PAIR Array

No. of Staves Energized	12	13	14	15	16	17
Required Amp. ON Time (sec)	1.24	1.44	1.64	1.85	2.05	2.27
Max. P_o Capability of Amp. (KW)	1.90	1.64	1.44	1.26	1.15	1.03

Table 2

Maximum Available Power per Amplifier versus Number of Energized Staves

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Source Level db//μbar/1 yd	12 Staves DI=23.9db BW=9.3° Tot. P_E (KW)	13 Staves DI=24.2db BW=8.7° Tot. P_E (KW)	14 Staves DI=24.4db BW=8.2° Tot. P_E (KW)	15 Staves DI=24.6db BW=7.8° Tot. P_E (KW)	16 Staves DI=24.8db BW=7.5° Tot. P_E (KW)	17 Staves DI=25.0db BW=[illegible]° Tot. P_E (KW)
134	23.7	22.0	21.0	20.2	19.2	18.3
135	29.7	27.8	26.7	25.3	24.2	23.2
136	37.5	35.0	33.3	31.8	30.5	29.2
137	47.2	44.0	42.0	40.2	38.4	36.7
138	59.4	55.3	52.8	50.5	48.2	46.0

Transducer efficiency 30%

Table 3

Alternating Current Power Required to Drive the PAIR Array

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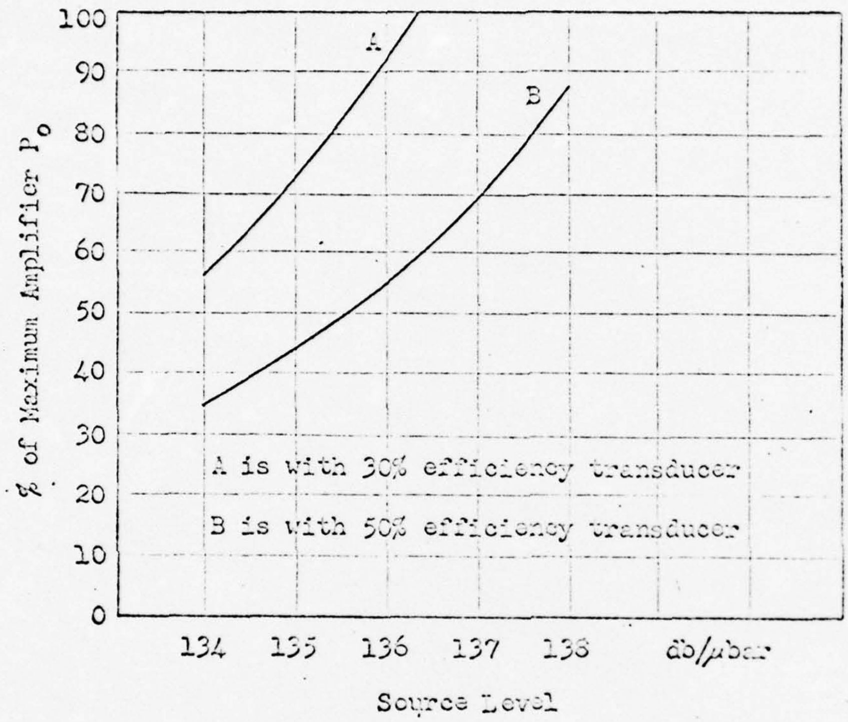

Figure 1

Percent of Maximum Amplifier Power Used
versus
Source Level

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I. TASK NUMBER: 17

II. TASK TITLE: Instrumentation

III. INVESTIGATOR: D. C. Lockingbill

IV. CONCLUSIONS:

A. <u>Recommended Changes to Specification</u>

No major changes to the contract specifications are required for this task.

B. <u>Suggested Improvements</u>

No suggested improvements in this area are indicated.

C. <u>Need for Further Investigation</u>

No further investigation on this subject is required.

V. DISCUSSION

A. For the most part the application of the instrumentation concept can be considered a vital part of testing. As such it must be woven throughout the test and evaluation planning procedure documents.

B. Instrumentation for the various subsystems of PAIR are incorporated in the equipment design and are not treated separately.

C. While not a part of the specifications being examined, whatever instrumentation in the way of test sets being supplied under the TRAM program will need to be integrated to the PAIR requirements.

Enclosure (17)

I. TASK NUMBER: 18

II. TASK TITLE: Performance Memory Equipment

III. INVESTIGATOR: D. C. Lookingbill

IV. CONCLUSIONS

A. Recommended Changes to Specification

No changes to the contract specifications are required for this task.

B. Suggested Improvements

This is GFE and as such, comments relative to modifications need to be directed to the TRAM Program.

C. Need for Further Investigation

Some follow-up should be provided to insure that the interface needs are met and to determine the final usefulness for operator training in the passive mode.

V. DISCUSSION

A. SHIPS-R-4928A, BUSHIPS Contract Specification, "Reliability Improvement Kit for AN/SQS-23 Series Sonar" gives the technical specification for the Performance Memory Equipment. An examination of these specifications shows several limitations to the use of this equipment for accurate performance monitoring, particularly in the passive mode. Among these are the limits on the low end of the frequency response for record/playback and timing errors between tracks due to dynamic and static skew in excess of the timing errors allowable within the resolution requirements for PADLOC.

B. Because of these present equipment limitations and because accurate performance monitoring is to be supplied for both active and passive modes as a part of the PAIR Program, the PME should only be considered as means for

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operator training and very gross system checkout for the active mode. Its usefulness for passive mode operator training will depend upon results obtained from performance testing of the prototype PME units how under procurement.

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I. TASK NUMBER: 19

II. TASK TITLE: Performance Monitoring and Fault Location

III. INVESTIGATOR(s): D. C. Lookingbill and E. Smith

IV. CONCLUSIONS

A. Recommended Changes to the Specification

No major changes to the contract specifications are indicated.

B. Suggested Improvements

1. Paragraph 3.4.5.20, Monitoring and Fault Localization, should be rewritten as follows:

a. 3.4.5.20 - Monitoring and Fault Localization

(1) 3.4.5.20.1 - Equipment shall be provided for on-line performance monitoring of the 48 active processing channels, the 24 forward and 24 aft passive processing channels, and the active track channel, from the input to the preamplifiers through the respective displays. Performance below an established limit will be indicated in such a manner on the display in each case, so as to be clearly brought to the attention of the operator.

(2) 3.4.5.20.2 - Fault localization shall be accomplished by injection of synthetic test signals into the subsystems using built-in test circuits.

(3) 3.4.5.20.3 - Both monitoring and localization shall be provided to the level of detail commensurate with system dependability requirements.

C. Need for Continued Investigation

A continuing review of the fault location and performance monitoring should be made as the relationship to reliability is established.

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V. DISCUSSION

In general the concept of performance monitoring and fault location as described in Appendix "P" of Volume IB, AN/SQS-23 PAIR document, is acceptable with several modifications.

1. Some of the TRAM work will result in sensors and monitors such as power amplifier cooling and output level. These outputs must be remoted to and integrated with the PAIR performance monitors.

2. Performance indication for the on-line performance monitors should be such that although proper performance can be distinguished by the operator, the emphasis should be in the indication for the unacceptable performance value. A marked increase in illumination of the display symbol or an alarm would call the operator's attention to the situation.

3. For the on-line performance monitor of the active processor, a counter could be provided to precess the anti-beam forming network during the interval just before and after the transmitted pulse. Provisions then should be made to override, hold, or reverse this precessing operation so that more than one look is available for each beam position if needed.

4. Because of the new format for the operating modes, the above on-line check should be programmed to operate with one of the detection pulses, for example, the 128 ms FM pulse.

5. For checking the active range and bearing calibration, signals are displayed at the bearing angle corresponding to the selected beam center. It is desirable for the sum and difference scanner operation to move this simulated target from a beam center to some point between adjacent beams.

6. The attached memorandum discusses the Sperry concept of performance monitoring and fault localization and relates that concept to a

more sophisticated system. While a central performance monitor and fault locator may be desirable at a later date it may not be in keeping now with the anticipated PAIR Program.

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MEMORANDUM

From: Edwin W. Smith, Code 3340 3 September 1965
To: Mr. R. D. Isaak, Code 2140

Subj: Performance Monitoring and Fault Location for the SQS-23 Modernization Project (PAIR)

Ref. (a) Code 2140-6-65 Memo of 19 August to Code 3340
(b) Sperry Gyroscope Co. AN/SQS-23 PAIR, Technical Report, Vol. 1A
(c) Sperry Gyroscope Co. AN/SQS-23 PAIR, Technical Report, Vol. 1B

1. In response to ref. (a), references (b) and (c) have been reviewed with attention being given to performance monitoring and fault location philosophy and details described therein. The comments and discussion which follow are submitted on the basis of technical information which is somewhat sketchy and general in nature. Additional details, explanation or interpretations of the basic material presently available would probably modify to a certain extent the viewpoints expressed.

2. General Philosophy

a. The general testing philosophy expressed in the Sperry proposal is to provide a centralized built-in monitoring and test facility within the main display console. For overall performance monitoring, simulated targets would be injected into the system, producing a display presentation uniquely identified, to be interpreted by the operator as an indication of the performance of the following:

(1) The 48 active processing channels from preamplifiers through display.

(2) The 24 forward plus the 24 aft passive processing channels from preamplifiers to display.

(3) The active track channel from preamplifiers to display.

In addition, all power supply voltages would be continuously monitored, with a single summary indication at the display console in the event that one or more of the power supply voltages goes out of tolerance.

It appears that the attention of the operator would be called to the fact that he has a power supply failure through use of the warning light

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(or possibly an audible signal). In order to be aware of failure when using the simulated target for performance monitoring of system performance characteristics other than power supplies, the operator must note the absence of the proper test pattern at the proper time and position on his display. This would appear to require his considered attention.

Output of the active processor will be compared to a norm and if this output lies outside the established limits for the test input, a visual alarm indication will appear. It is not clear how much of the overall acceptable performance of the processor and related equipment this alarm would cover.

3. Performance Monitoring

Except for the hydrophones themselves, it appears that deficiencies in overall performance of the system could be detected by an alert operator properly controlling the test signal insertion and properly noting the related display result or lack of it. In addition, it would appear that any power supply failure throughout the system would be promptly noted by any operator because of the simplicity of the indication.

In order to consider a more effective performance checking facility with less dependence on the time and initiative of the operator it is suggested that some modifications and additions to the existing facilities might be examined in terms of their potential cost effectiveness. Some of the capabilities and possible approaches are outlined below. Whether these are desirable in terms of cost effectiveness or even practical from a technical standpoint would depend upon the results of further study and information regarding system and circuit details. However, even though the capabilities or approaches are not found to be appropriate they may illustrate or suggest test capabilities and approaches which may deserve consideration.

If it is feasible to program the stimulus test and measure electrically rather than visually, its result for the various channels, bearings and/or ranges, the measured values might be compared electrically or digitally with the normal value to provide a continuously variable performance measurement or an acceptable/non-acceptable signal in electrical form.

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Assessment of performance from a location other than the operator position would require remoting facility for both the stimulus control and the comparison. At least a part of this operation appears already to be included in the facility for setting up remotely a test target (described in the manuals as intended for operator training or test). The second part of the operation would require that the test result and the position requested be expressed in electrical form for comparison with the electrical signals which specify and ask for the test target.

If the test target function is made electrical in both control and output, the performance assessment could more easily be made from an area and in a manner not requiring the services and attention of the operator, both of which may be variable in nature. NEL and the automatic test system code at the Bureau of Ships are advocating a trend toward centralized automatic testing of complex shipboard systems as may be justifiable by cost-effectiveness consideration. To the extent that this approach is possible, it avoids the inclusion of an elaborate automatic testing capability, complete with computer and large memory capability as an integral part of each large prime electronic system aboard ship. It is felt that a sharing of such a facility is practical and can be justified, whereas a complete test system of comparable capability cannot be justified for each prime system.

As a move in the direction of compatibility with a central testing capability and as a compromise with problems of existing equipment design and urgency, it is suggested that consideration be given to making the system performance test and its results suitable for remote operation and interpretation, with the alternative of local control and interpretation. Making the control of stimulus injection and the assessment of the result electrical in nature would assist in providing flexibility and adapting to both local and remote testing.

Apart from the question of remote and local operation of the performance check is the question of the convenience, ease, and completeness with which the check is made. From the Sperry material available the time required and the degree of involvement of the operator is not clear. Also, it is not clear whether an overall performance check can be made without some sacrifice of equipment availability for normal use. For example, there seems to be some doubt from the information available as to whether the performance check with the test target is testing the memory and range bins

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used operationally or is testing only the portion of these subsystems peculiar to the test target itself. It appears that it may not be possible to check the portions of these systems used for real targets without making a special set-up and interfering appreciably with normal operation. A goal, until it is shown to be not desirable from a cost effectiveness standpoint, should be a type of performance check which is automatically repetitive or programmable in its control, which alerts the operator when performance is degraded, and calls attention to at least the generalarea where the degradation is occurring. This performance malfunction alert signal should preferably be receivable both by operator and maintenance man.

4. Specific Malfunction Determination or Fault Localization

As has been stated in regard to Performance Monitoring, the material available in regard to specific malfunction determination and fault localization is general in its treatment of various points so that it is somewhat difficult to determine the degree of convenience accuracy and extent of malfunction coverage. However, it is obvious that a high degree of reliance is placed on the initiative, attention, comprehension, and interpretive ability of the operator. Although it is not felt at this time, because of cost-effectiveness reasons, that there should be an attempt to go completely automatic, it is felt that a worthwhile objective is to attempt to make it possible for an operator with very limited technical training to localize trouble to small functional areas or preferably to a replaceable unit or units without the necessity for multiple patching or interrelated switching operations, or technician type scope interpretations.

The power supply malfunction indication proposed by Sperry is illustrative of the simplicity of interpretation needed for the non-technical operator. However, it would be preferable to attempt to retain the simplicity of interpretation for the inexperienced operator without at the same time throwing away the detailed information which can be utilized by the experienced technician for real diagnosis.

Sperry proposes to use threshold detectors, set for normal values, providing a go/no go output, dependent upon the comparison between the

threshold and the voltage at the test point. Although this approach seems very attractive in its apparent simplicity and economy, a number of difficulties have become apparent where this approach has actually be employed:

a. There is considerable difficulty in setting a limit which is neither too tight nor too loose, Ifthe limit is too tight the operator is forced to consider some no-go's as go's under certain circumstances. If the limit is too loose, the operator will not have an indication of malfunctions which may be real but not large enough to reach the threshold. It is important to recognize that in typical shipboard equipment systems there may be appreciable variations in absolute readings for what is regarded as acceptable performance from day to day, depending upon age of equipment, temperature, humidity, variation in replacement parts, etc. In the practical shipboard situation, the technician has neither the time nor inclination to recalibrate these thresholds in sensors within the equipment on a daily basis or even less frequently. Hence it is considered preferable to provide a measurement of the value at the test point which can be interpreted against a comparison reference which is provided further down the test system and which can be more easily adjusted than at the test point itself. Expressed differently, unless the threshold is adjustable remotely, a go/no-go type of measurement is by its nature a binary measurement of one-bit accuracy. This accuracy is not sufficient for many fault assessment purposes. A measurement equivalent to at least five or ten bits in accuracy may be no more costly than the one with one-bit accuracy. (Considered system-wise it may even be less costly in some cases because there may be fewer measurement devices if the measurement is made remotely by a single device) The less significant bits may then be thrown away further down the measurement system at such time or point that the fineness of interpretation dictates the accuracy required. In general, it is important to note that the operator, for gross performance assessment, does not require the degree of accuracy of measurement required by the technician for fault diagnosis. This is particularly true where the fault is complex and is not a simple one with a single obvious effect.

The treatment of power supply measurements for fault isolation purposes just discussed is the simple case, as compared with a measurement of other more complex signals and performance. However, in general the same basic approach is recommended. It is suggested that the signal or performance

of a unit be measured with accuracy usually considerably greater than that of one binary bit. Frequently, it is the relative accuracy or stability of measurement which is most important for performance assessment and for at least the first steps of fault isolation. In many cases an accuracy of five or six bits is sufficient, particularly if the sensor is placed at a strategic point in the circuit or sub-system. Some of NEL's R1-9 work is currently directed toward development of micro-circuit sensors, for sensing steady state signals and pulses, including single pulses. Sensors are addressable remotely by a serial pulse-train type code. Outputs of the sensors provide a low voltage dc output, as a measurement of dc, ac, and pulse characteristic. The dc output of the sensors is suitable for measurement at the operating equipment, but is primarily intended to feed into a dc to frequency converter (also in micro form), for transmission to a central automatic test system console. Sensor data is stored and processed digitally, with percentage deviation of the total permissible deviation being displayed against selected block diagrams of the system. Storage and processing of sensor data employ digital techniques. The basic Automatic Test System under development is expected to provide a basis for procurement of centralized shipboard automatic test systems intended for performance monitoring and to assist at least in the initial steps of fault isolation in several major systems, including those of the AN/SQS-23 type. Although it is recognized that each major system may have monitoring and fault location problems peculiar or unique to it, because of electronic or mechanical features, it is also recognized that there are many problems common to all systems currently in use or contemplated for use shortly.

For compatibility with such a centralized automatic test system, it is recommended that, within the limits set by good cost-effectiveness consideration at this time, an attempt be made to provide sensors which are remotely addressable by a serial pulse code and which provide dc, digital, or frequency outputs suitable for line driving. As pointed out by Sperry as a reason for their heavy reliance on the man in their test approach, an attempt to go completely automatic can be prohibitively expensive and probably would not be practical in the time scale. However, it is felt that considerably more assistance can be provided to the operator and technician performance in monitoring and fault location than appears to be proposed in the Sperry technical volumes.

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5. Summary and Recommendations

a. It is not felt that anything outlined in the Sperry monitoring and fault location approach is impracticable or unreasonable. The facilities and approach proposed would appear to offer considerable improvement over the approach which would be employed if only conventional test points were provided to the technician for use with conventional test equipment.

b. It is recommended that consideration be given to further improvement of the proposed capability by inclusion, as feasible, of sensors, data feeds and some remotely programmable test features to better adapt the test approach and facilities to computer-aided performance monitoring and fault location, as well as greater convenience in local control and interpretation of test results.

Edwin W. Smith
EDWIN W. SMITH

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I. TASK NUMBER: 20

II. TASK TITLE: Classification

III. INVESTIGATOR(s): J. Reardon, H. R. Eady, L. Mulcahy, J. Baxter

IV. CONCLUSIONS

A. Recommended Changes to Specification

1. Section 3.2.2.2 (f): Substitute for "the probability of a target being a submarine." the statement: "the relative likelihood that the inserted clues would be produced by a submarine rather than a non-submarine contact."

2. Section 3.4.5.21: Substitute for "to obtain from a display the a posteriori probability of a submarine target" the statement: "to obtain from a display the relative likelihood that the inserted clues would be produced by a submarine rather than a non-submarine contact." Delete "Provision shall also be made for manually injecting a quantized level of the a priori probability of a submarine target.'

3. Section 3.4.5.21.2 Substitute for "The output shall be a number displayed at the console and indicating, to ten discrete levels, the probability of a target being a submarine." the statement: "The output shall be a numbered light displayed at the console indicating one of ten discrete levels of relative likelihood that the clue input entered would be produced by a submarine rather than a non-submarine contact."

4. Section 3.4.5.5 Substitute for "A digital doppler discriminator shall be provided for operation with either SBR in the CW mode with the 32 and 128 millisecond pulses" the statement: "A digital doppler discriminator shall be provided for operation with either SBR in the CW mode with all pulse lengths."

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Enclosure (20)

Task No. 20

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5. Section 3.4.5.13.2 Substitute for "For the 32 and 128 milliseconds pulse lengths in the CW mode, the difference output of the doppler discriminator shall be presented in a vertical A-scan presentation." the statement: "For all pulse lengths in the CW mode, the difference output of the doppler discriminator shall be presented in a vertical A-scan presentation."

6. Section 3.4.5.14.4 Change ".011 inches" to ".020 inches".

7. Section 3.4.5.21.1 In the list of clues, change "Left Edge Alignment" to "Edge Alignment".

8. Section 3.4.5.14.5 b Substitute for "They shall have a nominal writing width of 1/32 inches and be in the darkest tone shade" the statement: "They shall have a nominal writing width of 1/32 inches and be in the darkest tone shade for mode A and one of the lighter tone shades for modes B and C".

B. Suggested Improvements

1. A line separation of .040" is suggested for the active recorder.

2. The doppler clue evaluator level definitions would be less confusing if labeled: Marked-up, Medium-up, Zero, Medium-down and Marked-down.

3. It may be advisable to make the TRR gate sizes the same as the TCD gate sizes.

C. Need for Continued Investigation

1. Considerable study and analysis should be done on the doppler discriminator performance.

2. The effects of various proposed non-alerting transmit sequences on the classifications capabilities of PAIR should be investigated in detail.

3. Efficient use of the proposed TRR by the operator requires further study (see Task Number 8 - Display, Section V - DISCUSSION)

4. The equations to be implemented for the clue evaluator need to be defined as do the tests which should be run to evaluate them

V. DISCUSSION

A. Clue Evaluator Output:

A posteriori probability as an output of the clue evaluator is considered by NEL and Human Factors Research, Inc., to be technically premature. Lack of knowledge of *a priori* probabilities plus no precise definition of absolute likelihood ratios for clue inputs would make *a posteriori* probability values sheer guesstimates and would likely result in subsequent errors that would undermine confidence in outputs. The use of only relative levels of likelihood that clue inputs are produced by a submarine contact is more commensurage with our present state of knowledge. The output lights should be labelled 1 through 10 with no implication of absolute output values.

Notions of *a priori* probability as well as the potential cost and value structure prevailing in any given tactical situation can be applied at command level in terms of which output light will be used at the time as the dividing line between a submarine and a non-submarine decision.

B. Doppler Discriminator:

Use of a stepped AGC prior to this device might introduce switching transients which would be counted as axis crossings of either the reverberation or the echo. If transients are introduced, efforts should be

made to insure that they do not cross the analog signal axis. An alternative approach is to not use any AGC on the signal fed to the doppler discriminator.

High frequency circuit noise or electrical transients present at the input to the doppler discriminator can use the axis crossing counter to count faster than it should. This will occur when the sonar input signal amplitude is low, relative to the amplitude of the noise or transients. These effects can be reduced by proper isolation and design of the circuits.

If the clipper has an axis crossing threshold other than zero, and the sonar signal amplitude falls below this threshold, some axis crossings will be missed. This problem can be minimized by proper circuit design.

Since the latter two problems usually occur when the sonar signal amplitude is low, an alternative approach would be to threshold the input signal and accept only those axis crossing intervals which belong to signals exceeding this threshold.

The recommendation that doppler output be made available for all three CW pulse lengths is made because the 4 millisecond pulse may provide some useable doppler information from the axis crossing type doppler discriminator.

C. TRR:

There is an incompatability between the passive recorder and the active recorder in line width requirements because the former has extremely long integration time compared to the latter. The active recorder may see only a few lines (10 or less) and needs good demarcation of each individual line. A line width of .020 inches with a line separation of .040 inches is suggested for the active recorder. For ten or less lines this will do the best job of defining edge alignment and will provide adequate correlation of highlight structure.

It is recommended that the range reference marks on the TRR be printed in one of the lighter tone shades to minimize interference with target traces. These marks should appear on each line printed since there may be only a few lines involved in many situations.

D. Transmission Sequences

The primary basis of the clue evaluation approach adopted in the proposal is that a fairly large number of looks at the contact are obtained in a reasonably short period of time. For reliable indication of some of the clues, selected directional transmission is required.

Thirdly, a combination of both short and medium or long CW pulses are required to obtain the complete set of clues for entry. The combination of these requirements makes it difficult to satisfy conditions of simultaneous search and classify and avoidance of super-alerting a possible target. The transmission sequences discussed in Task Number 11 (Operating Modes) are the best compromise that can be offered presently.

Essentially two techniques are proposed. The first includes the means for increasing data rates on contacts that are at shorter ranges than the search scale. In this situation, appropriate combinations of CW medium or long pulse and short pulse are transmitted at regular intervals during the entire search reception cycle, the time sequence depending on range of the contact. Data rates for most of these sequences are still low compared to ideal but they are better than anything suggested in the original proposal. Anywhere from 150 seconds to 726 seconds is required to obtain the minimum of five doppler pulses (32 or 128 milliseconds) and ten high resolution pulses (4 milliseconds). Anything less than this sequence will not provide all the clue inputs.

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The use of searchlight transmission continuously will decrease target alerting somewhat but the training of this beam on a target for 15 successive transmissions is bound to have some alerting effect. The only alternative (RDT CW pulses) is unattractive from the standpoint of time required and the degradation of certain clues.

An alternate mode designed to get more looks in a shorter interval of time is the burst mode. This will help take care of long range targets and can also be used on shorter range targets if the time intervals of the first mode prove too great for good ping-to-ping clue correlation. The burst mode complicates graphic recorder operation but should be solvable.

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U. S. NAVY ELECTRONICS LABORATORY
SAN DIEGO, CALIFORNIA 92152

IN REPLY REFER TO:
S27-20
Task 8573
(NEL J71461)
Ser 2140-017

NOV 24 1965

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From: Commanding Officer and Director, U. S. Navy Electronics Laboratory, San Diego, California 92152
To: Chief, Bureau of Ships (Code 1633)

Subj: AN/SQS-23 Sonar Letter Report Addendum

Ref: (a) NEL conf ltr S27-20 task 8573 (NEL J71461) ser 2140-03 of 22 September 1965

Encl: (1) Task 21, Addendum 1, Performance and Operations Analysis of 22 November 1965 (CONFIDENTIAL)

1. Reference (a) is a letter report which treats the technical aspects of the AN/SQS-23 PAIR sonar. In the original letter report the chapter devoted to Performance was incomplete. The addendum enclosed herein (Enclosure (1)) is a replacement for the original Task 21, and it gives only the first portion of the entire performance prediction--that related to active detection for a single typical layer condition. It should be noted that the layer depth has a significant effect upon propagation loss and therefore detection range for both in-layer and below-layer targets.

2. The addendum which was prepared by TRACOR using the analytic modeling work of both NEL and TRACOR teams, treats the AN/SQS-23 and the PAIR modified SQS-23 in a like manner.

3. Range ratios of 1.3 and 1.8 for in-layer targets and below-layer targets respectively are conservative but indicate a definite range advantage of the PAIR sonar. The other planned improvements, e.g.: track-while-search, greater reliability, normalized display, simultaneous active and passive, target classification, etc; are not treated, so they should be an additional bonus.

4. A second addendum will be issued upon the completion of the analysis work treating the no layer active detection case and the passive detection case.

R. D. Isaak
By direction

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22 November 1965

I. TASK NUMBER: 21, Addendum 1

II. TASK TITLE: Performance and Operations Analysis

III. INVESTIGATORS: Dr. W. Watson, NEL
Dr. B. Brown and Dr. J. Beard, TRACOR

IV. CONCLUSIONS:

A. Recommended Changes to the Specification

None

B. Suggested Improvements

None

C. Need for Continued Investigation

In the discussion which follows, the performance of the PAIR sonar was compared with standard AN/SQS-23 sonar in the deep and shallow water situations with a 100 foot layer active detection operation only. Work is now in progress to examine two other cases: (1) No layer, active detection and (2) passive detection. In the future it is anticipated that the classification and tracking capabilities may also be treated.

V. DISCUSSION

The attached Performance Comparison gives the predicted active detection performance of both the standard AN/SQS-23 and the PAIR. The work, which utilized both NEL's sonar prediction model and TRACOR's sonar simulation model is divided into four primary parts: Introduction and Summary, Detection Range Comparison, Mutual Interference Comparison and Required Ship Spacings. A fifth part of the addendum lists the Modeling Parameters and Assumptions made in the study.

Enclosure (1) NEL ltr S27-20 Task 8573 (NEL J71461) ser 2140-017

22 November 1965

PERFORMANCE COMPARISON OF THE AN/SQS-23 AND PAIR

I. INTRODUCTION AND SUMMARY

The relative effectiveness of PAIR and the AN/SQS-23 has been estimated in four operational situations:

1. Target in a 100 ft layer in 1400 fathom water
2. Target below a 100 ft layer in 1400 fathom water
3. Target in a 100 ft layer in 100 fathom water
4. Target below a 100 ft layer in 100 fathom water

These comparisons are based upon determination of detection probability as a function of target range during particular tactics including crossing, parallel passing and constant aspect runs. For the PAIR, which is an ideally normalized system, the determination of the detection probability is direct. For the AN/SQS-23 the process involves two steps:

a. Determination of detection probability under the assumption that the scanner display is well normalized.

b. Estimation of the area of the display in which this assumption is actually valid and reduction of the effectiveness accordingly.

A second comparison provides plots of relative target and background levels as a function of range in single and multipship operation.

These two comparisons determine (1) the maximum separation of ships required to control a given ocean area for the PAIR and the AN/SQS-23 and (2) the minimum allowable separation under conditions in which mutual interference is not to be excessive. Using these results, one can then estimate the number of AN/SQS-23 ships and the number of PAIR ships required to control a given area of ocean.

The results obtained from this study of the comparison of the PAIR and AN/SQS-23 effectiveness for a 100 foot layer are given in detail in Sections II, III, and IV. A Summary of results is presented below.

1. In setting up a line of ships spaced to detect all below-layer targets as the line proceeds, about twice as many AN/SQS-23 ships as PAIR ships will be required.

2. (a) The required spacing of PAIR ships in this operation is approximately 10 kyd. At this spacing direct arrival during entire transmitter on time is the only significant source of mutual interference.

(b) If two separate frequency bands are utilized in RDT by adjacent ships, the nearest interfering ship is at 20 kyd.

(c) If crossed slides are employed by the ships spaced at 20 kyd, the interference will not result in display marking but will prevent detection of targets on the average of 10% of the time on the 20 kyd search scale.

(d) The next earest interfering ship is at 40 kyd.

3. Silent sectors provide very little additional freedom from direct arrivial interference (at most 1%). The increase complexity of the circuits and of the additional operator duties completely offset any advantage they provide. This conclusion is not meant to remove the requirement for a zero-time skip through the stern sector.

4. Rumble (the reverberation from other PAIR ships) is not a problem when the ships are at the required spacing.

5. The ratio of maximum detection range of PAIR to that of AN/SQS-23 is estimated at 1.3 for targets in a 100 ft layer and is estimated at 1.8 for below-layer targets.

II. DETECTION RANGE COMPARISON

The bulk of the detection range comparisons have been carried out with the NEL sonar performance modeling program*. Three types of geometries were considered at ship and target speeds of 15 knots and 5 knots respectively:

Type 1. The target travels in a straight line at an angle θ relative to own ship heading and crosses own ship path at a distance R ahead of own ship. R and θ are adjustable. This is a variable aspect run.

Type 2. The target and own ship travel parallel courses in opposite directions. Course separation and initial positions are adjustable.

Type 3. The target and own ship move in straight lines maintaining constant aspect. Aspects were chosen to give three values of target strength: 10 db, 15 db and 20 db.

The first runs attempted were Types 1 and 2. Typical runs are shown in Figures II(a) through II(f). The plots shown single ping detection probabilities** for both the PAIR and the AN/SQS-23 as a function of runage in a 100 ft layer in 100 fathom water. The results seem somewhat optimistic to those who have experience with the AN/SQS-23, but it is apparent that the PAIR detection range exceeds even the optimistic SQS-23 detection range by a significant factor.

It soon became apparent that runs of Types 1 and 2 were inefficient approaches to determining the area of ocean which could be surveyed by a single ship. The constant aspect runs

---

*The sonar performance prediction modeling program was developed by Dr. W. H. Watson and the results reported herein were obtained by him using parameters selected as described in the text.

**Both the PAIR and the AN/SQS-23 have ping-to-ping integration which will be expected to improve the performance about 3 db in the case of the PAIR and somewhat less in the case of the SQS-23. A 5-ping history appears on the PAIR display; ping-to-ping integration in the SQS-23 depends upon operator memory and alertness.

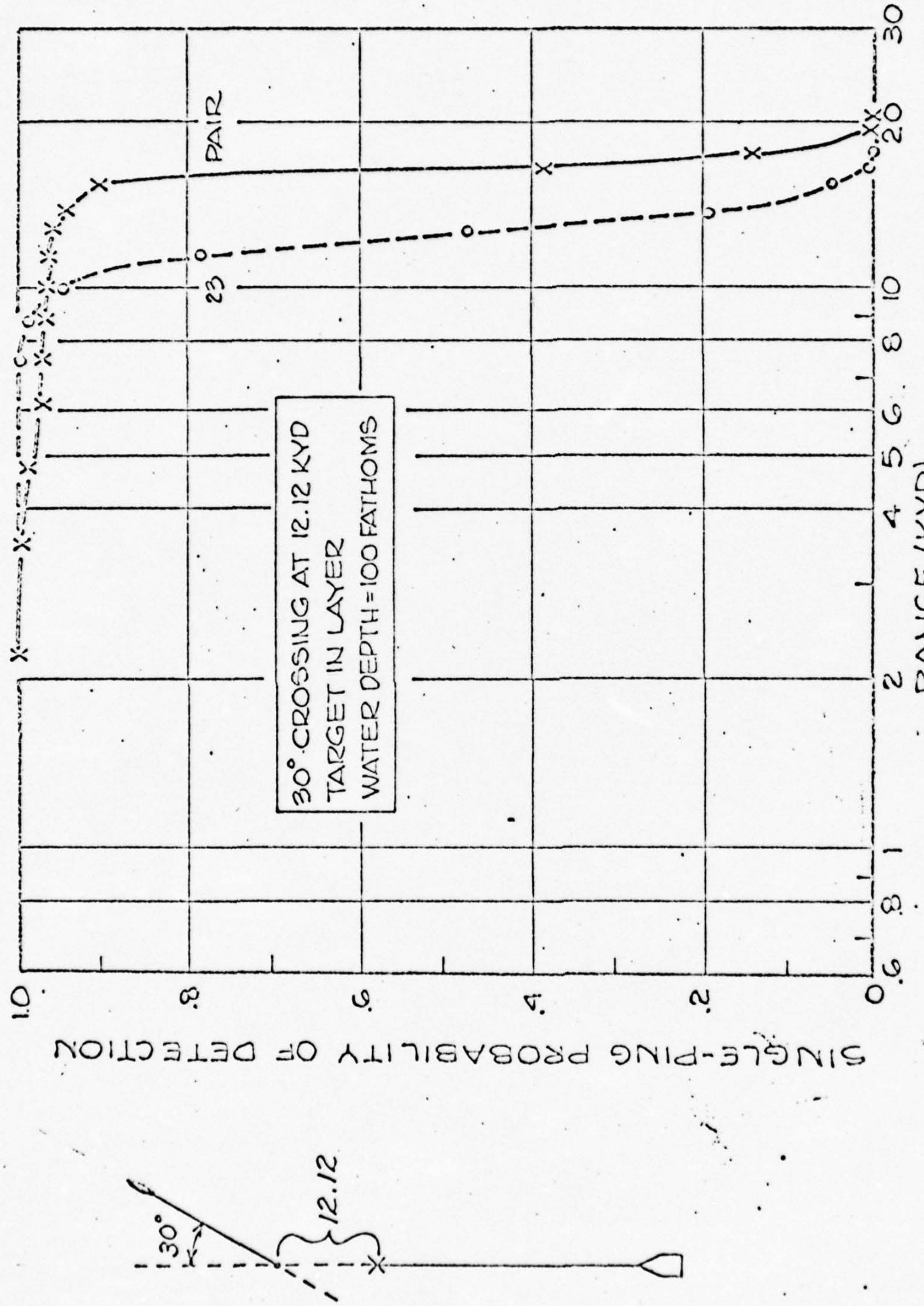

FIG. II(a) - CROSSING TACTIC DETECTION PROBABILITY

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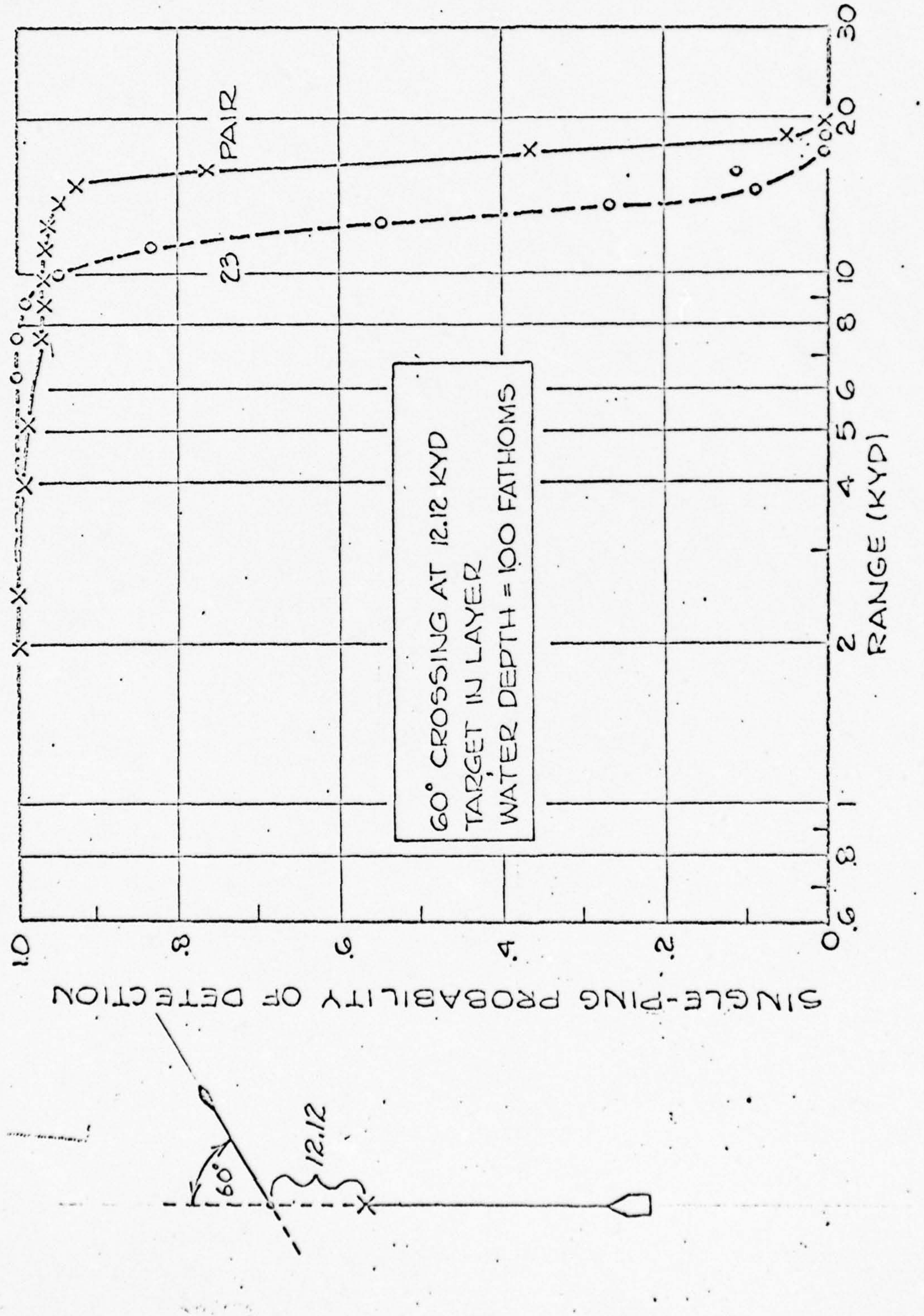

FIG. II (b) - CROSSING TACTIC DETECTION PROBABILITY

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11/15/65 /A4

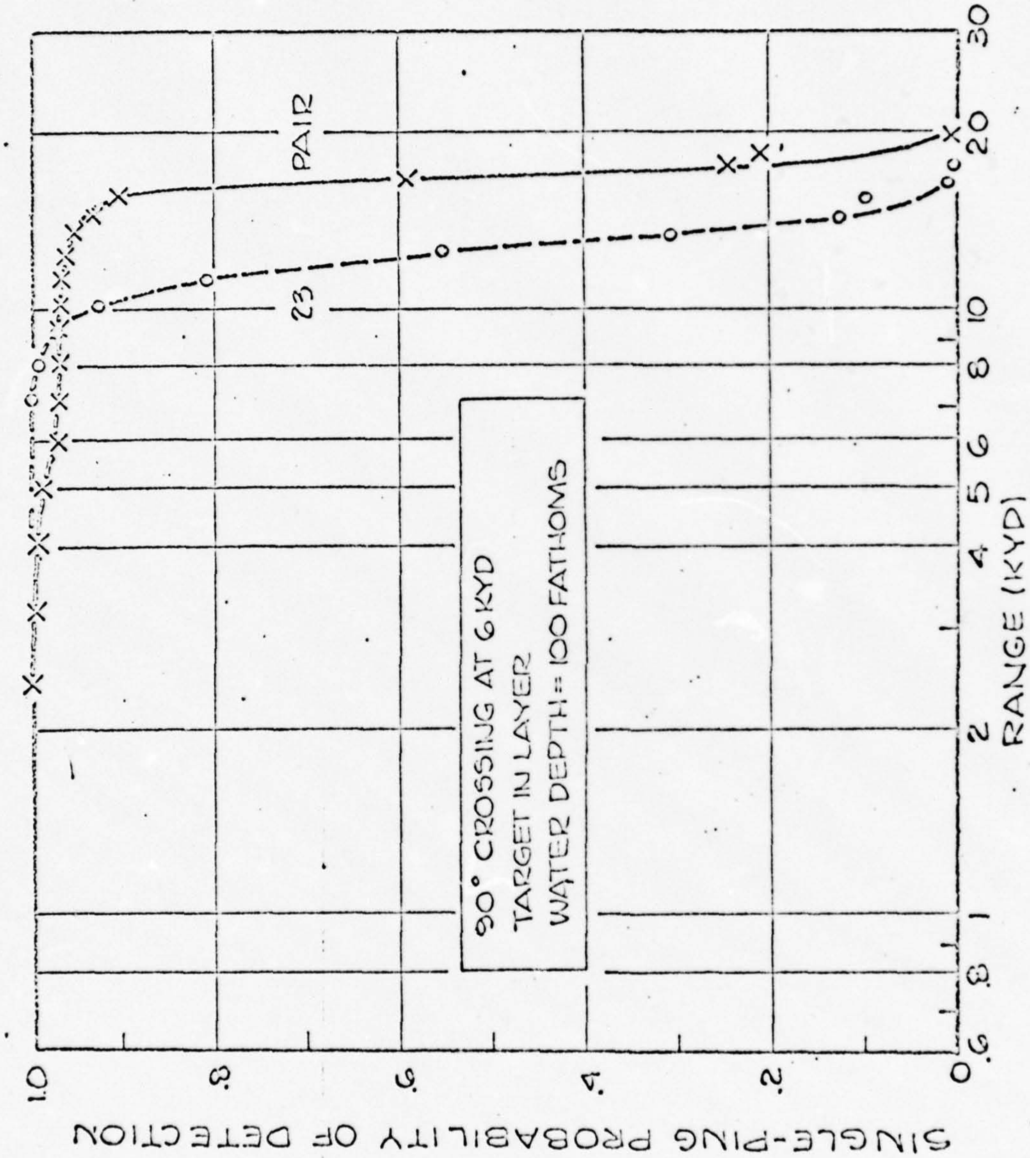
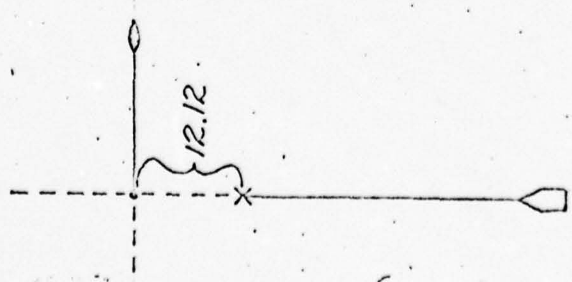


FIG. II (C) - CROSSING TACTIC DETECTION PROBABILITY



I DWG 6312
11/16/65 /AA

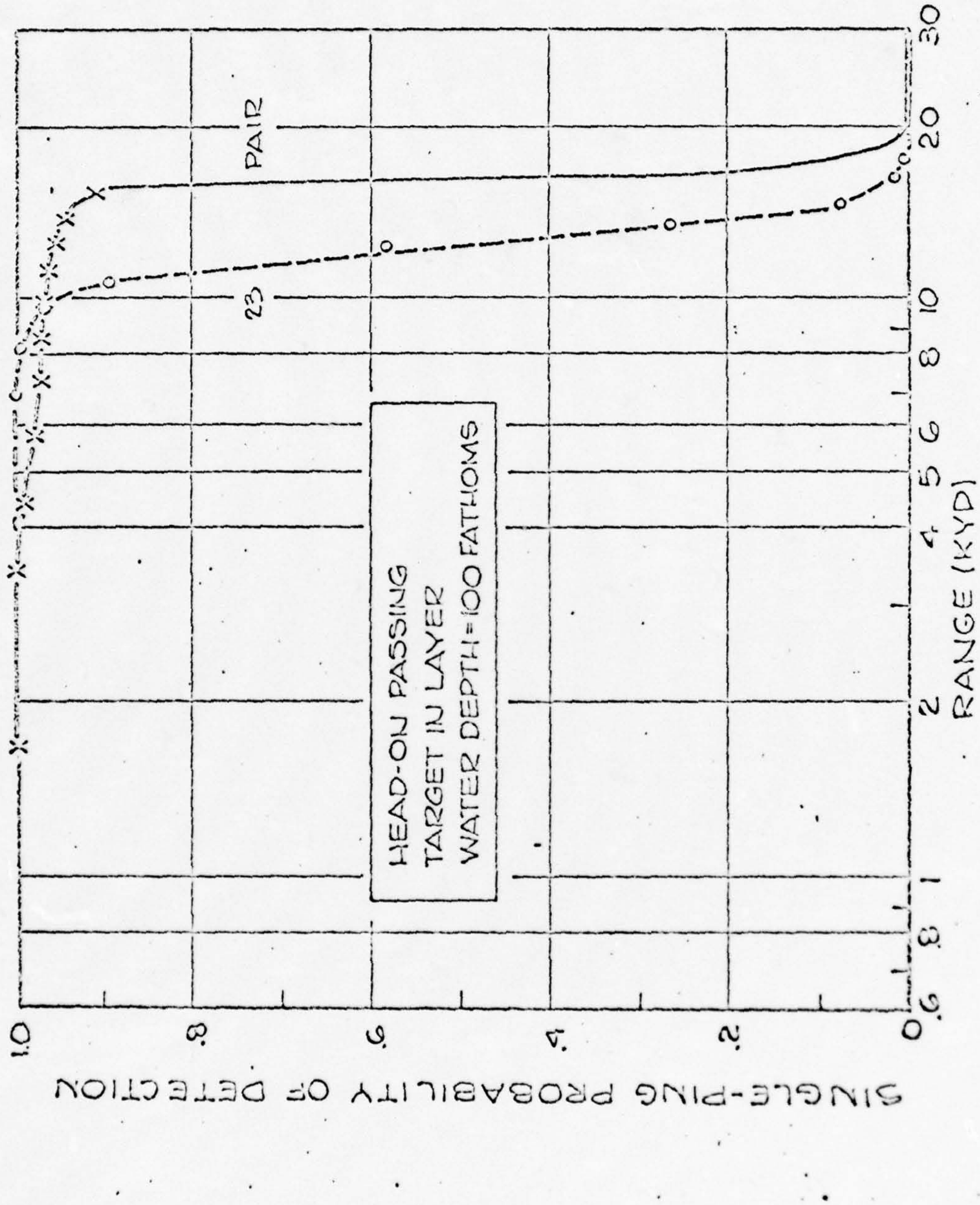
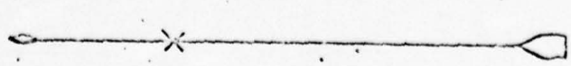


FIG. II (d) - PASSING TACTIC DETECTION PROBABILITY



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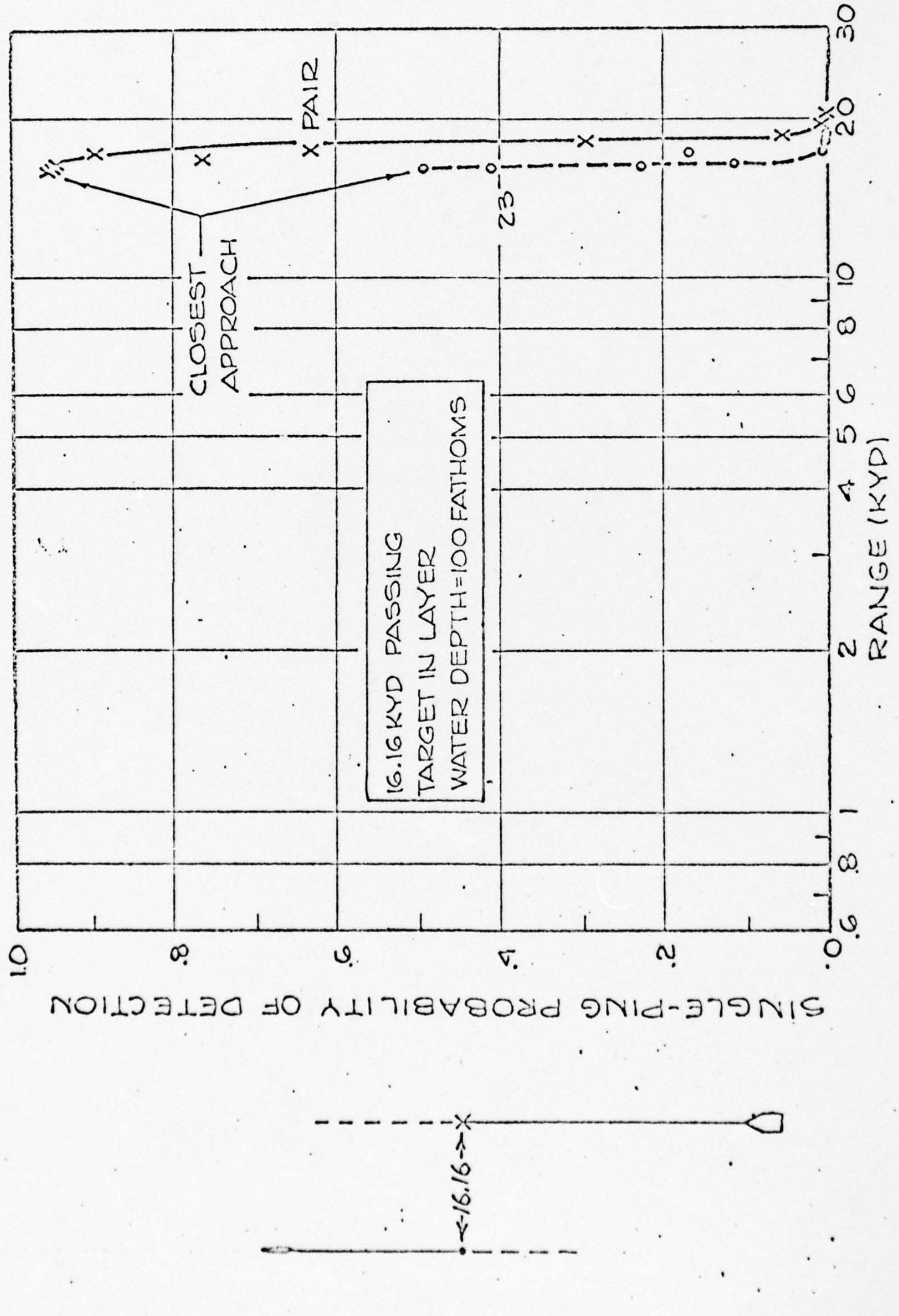

FIG. II (e) – PASSING TACTIC DETECTION PROBABILITY

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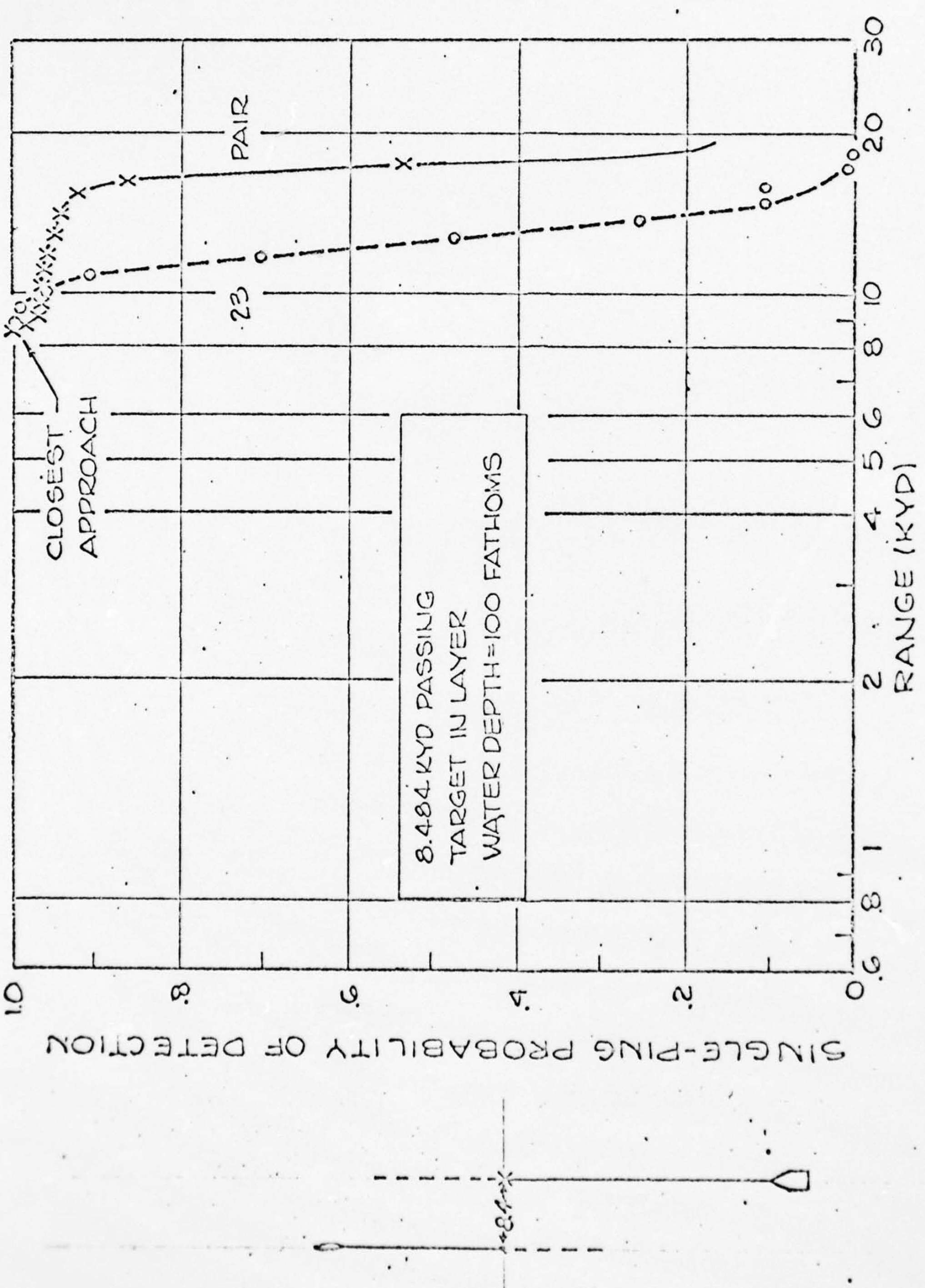

FIG. II (4)- PASSING TACTIC DETECTION PROBABILITY

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(Type III) were substituted for completing the determination. The detection probability plots for these runs are shown in Figures II(g) through II(r) for three aspects. As in the previous figures, one sees that there is an abrupt increase in detection probability in the neighborhood of the 50% detection region, the detection probability rising from less than 0.10 to more than 0.90 in a few kiloyards. The ranges for 0.50 probability of detection are tabulated:

Table I
Ranges (kyd) for Detection Probability = 0.50
(Layer Depth = 100 ft)

	PAIR			AN/SQS-23			Average Range Ratio
Target Strength (dB):	10	15	20	10	15	20	
Shallow Water (100F)							
In Layer	16.5	18.1	20	12.5	14	15.5	1.30
Below Layer	5.2	6	7.2	2.8	3.3	4.1	1.81
Deep Water (1400F)							
In Layer	16.5	18	20	12.5	14	15.5	1.30
Below Layer	5.3	6	8	2.8	3.6	4	1.81

The range ratios tabulated show that the PAIR exceeds the AN/SQS-23 in performance, providing 1.3 times the detection range for in-the-layer targets and 1.8 times the detection range for below-the-layer targets.

The predicted results are supported to some extent by the tabulations prepared* from fleet logs of sonar performance.

*The tabulations were obtained from Dr. W. H. Watson. The examples included in the tabulation included in-the-layer targets with layers of 100 ft ± 40 ft and below-the-layer targets.

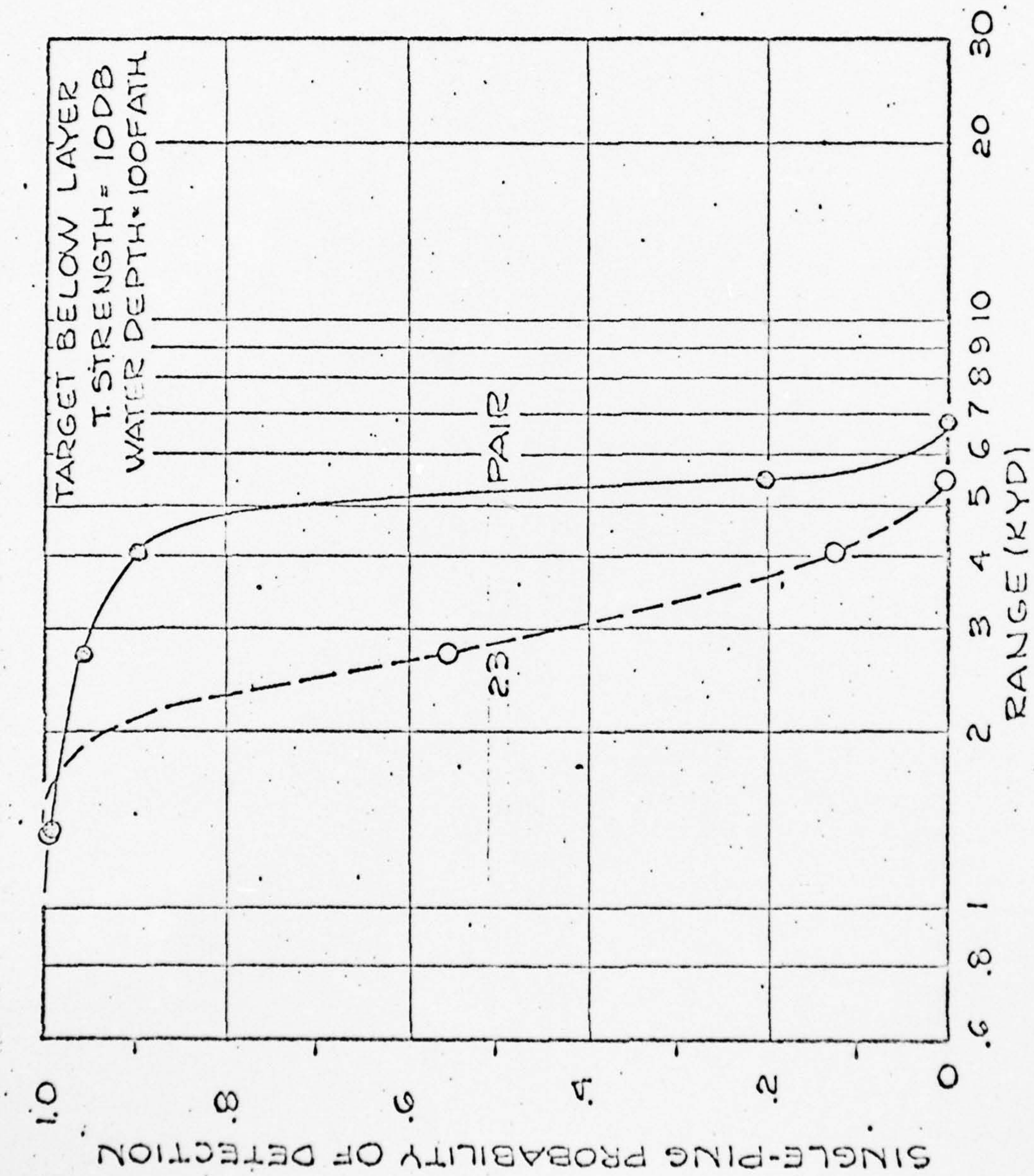

FIG. II (G)—CONSTANT ASPECT DETECTION PROBABILITY

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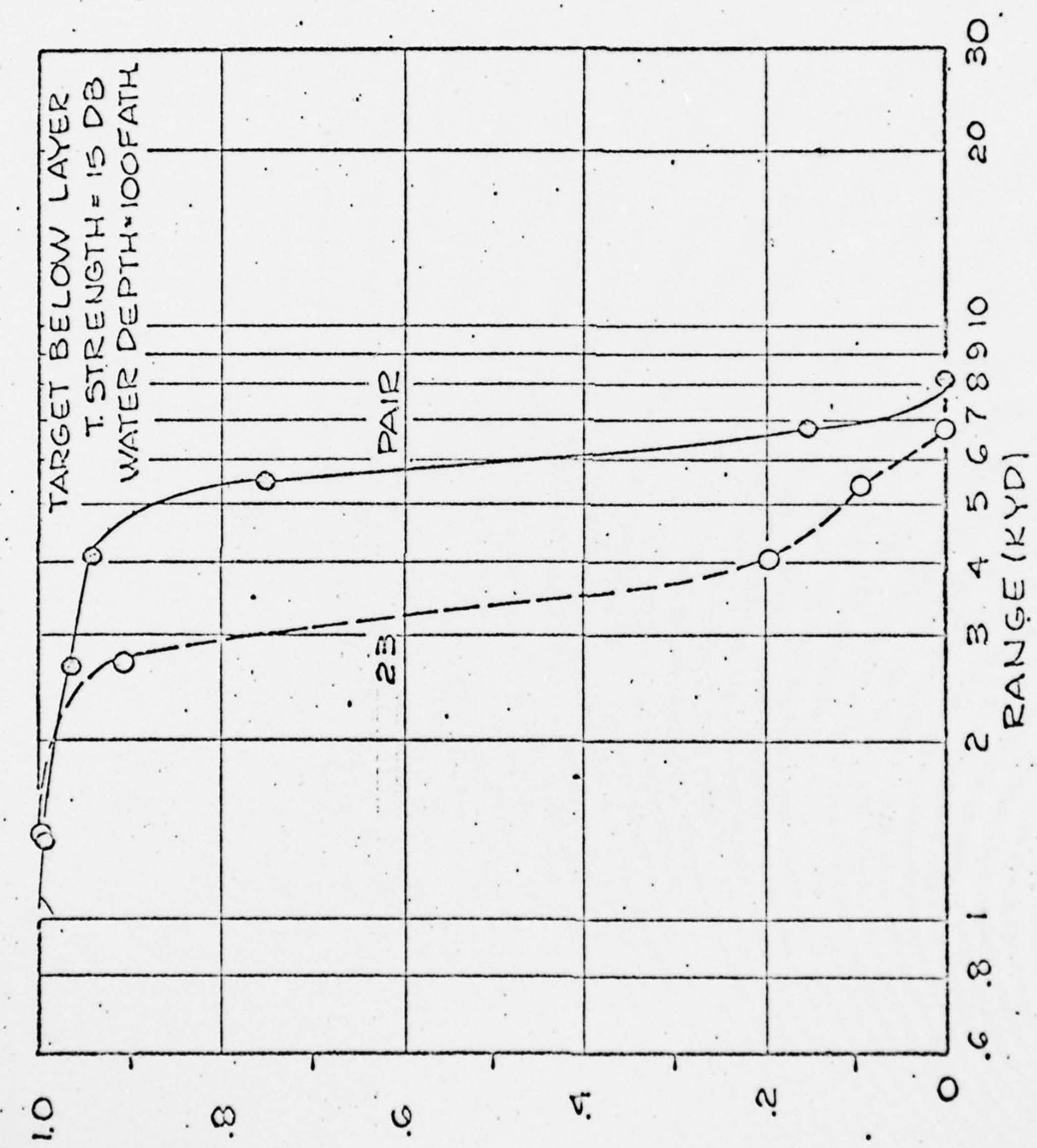

FIG. II (H) — CONSTANT ASPECT DETECTION PROBABILITY

DWG

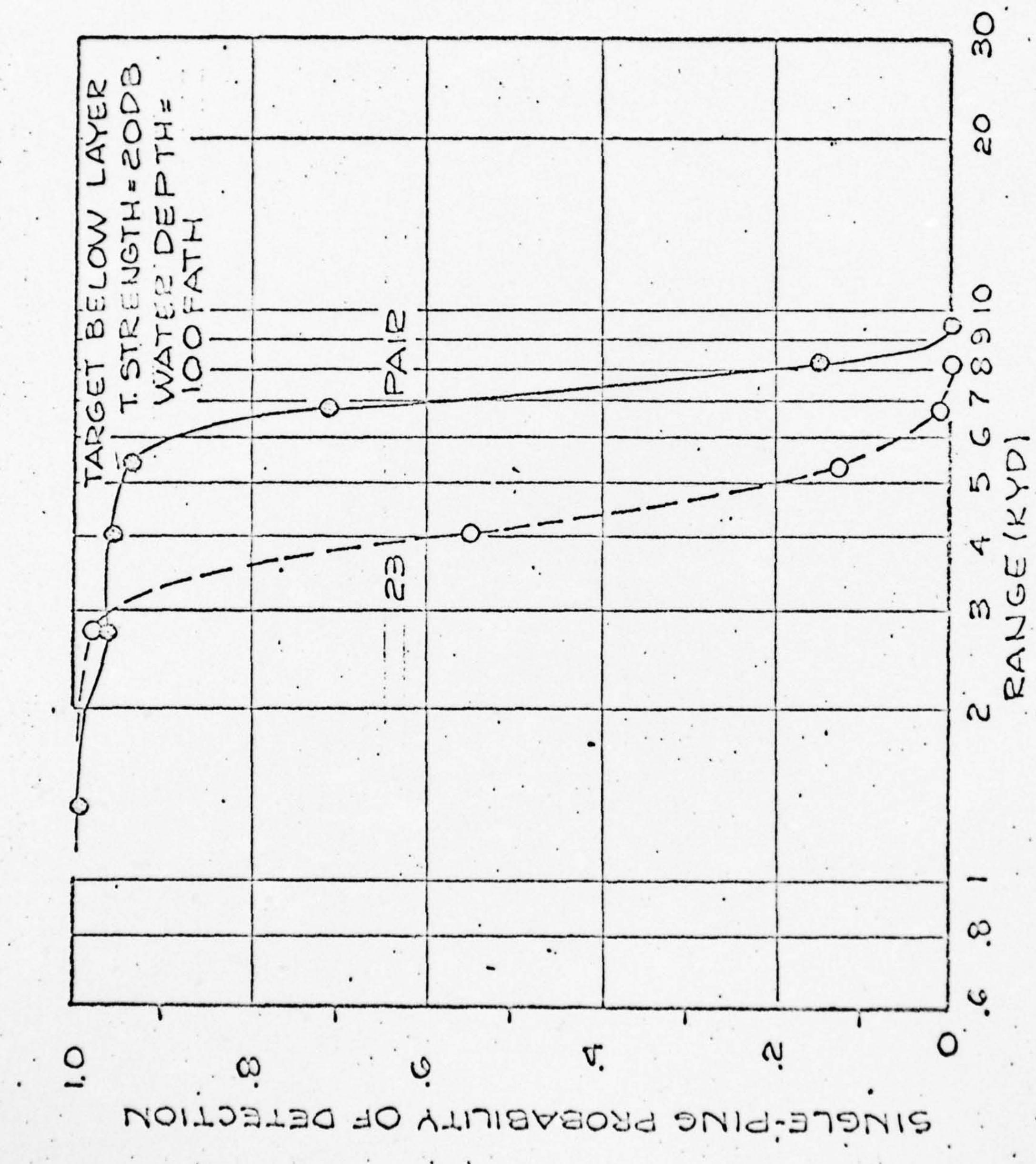

FIG. II(1)-CONSTANT ASPECT DETECTION PROBABILITY

DWG

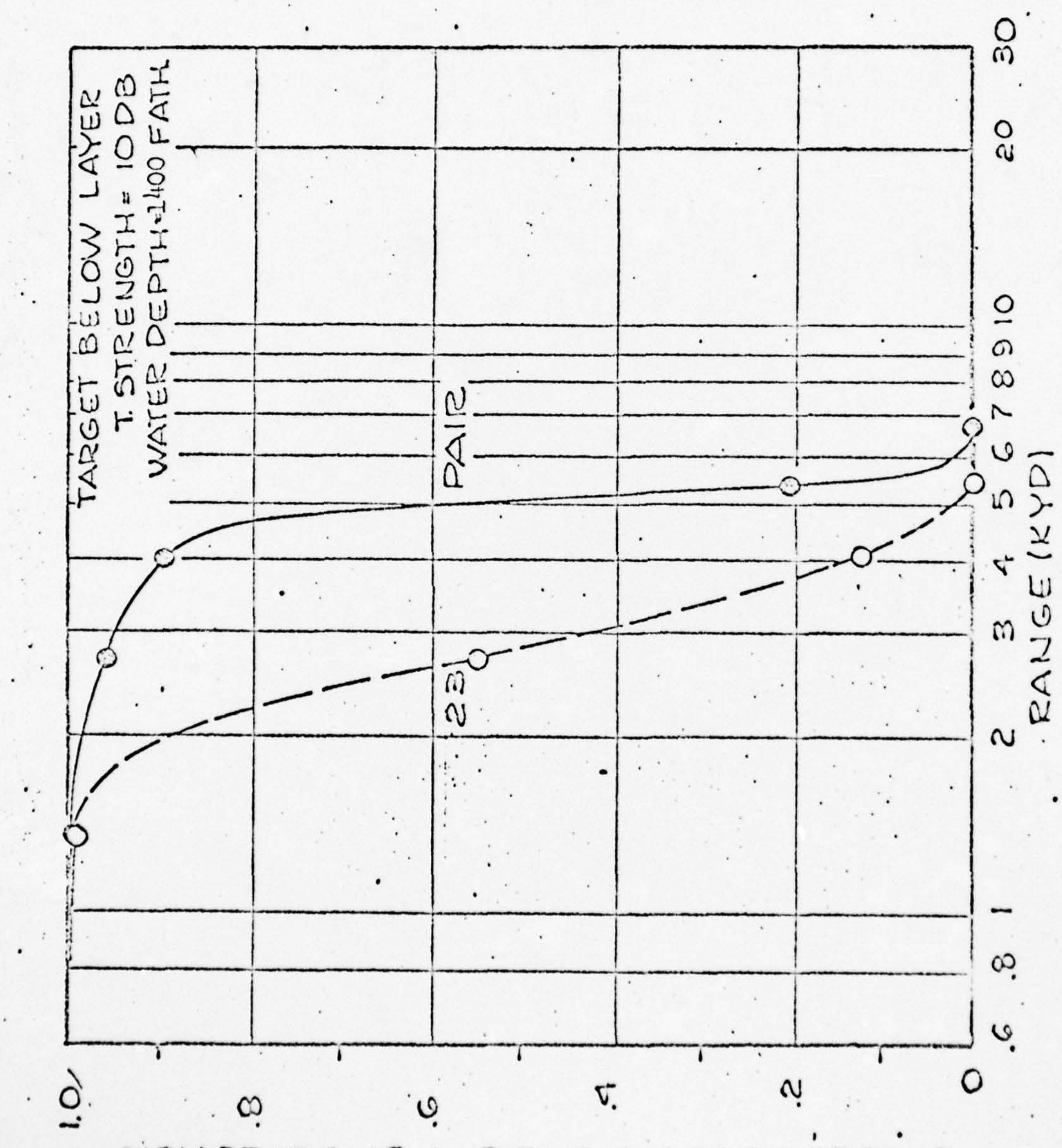

FIG. II(J)-CONSTANT ASPECT DETECTION PROBABILITY

DWG

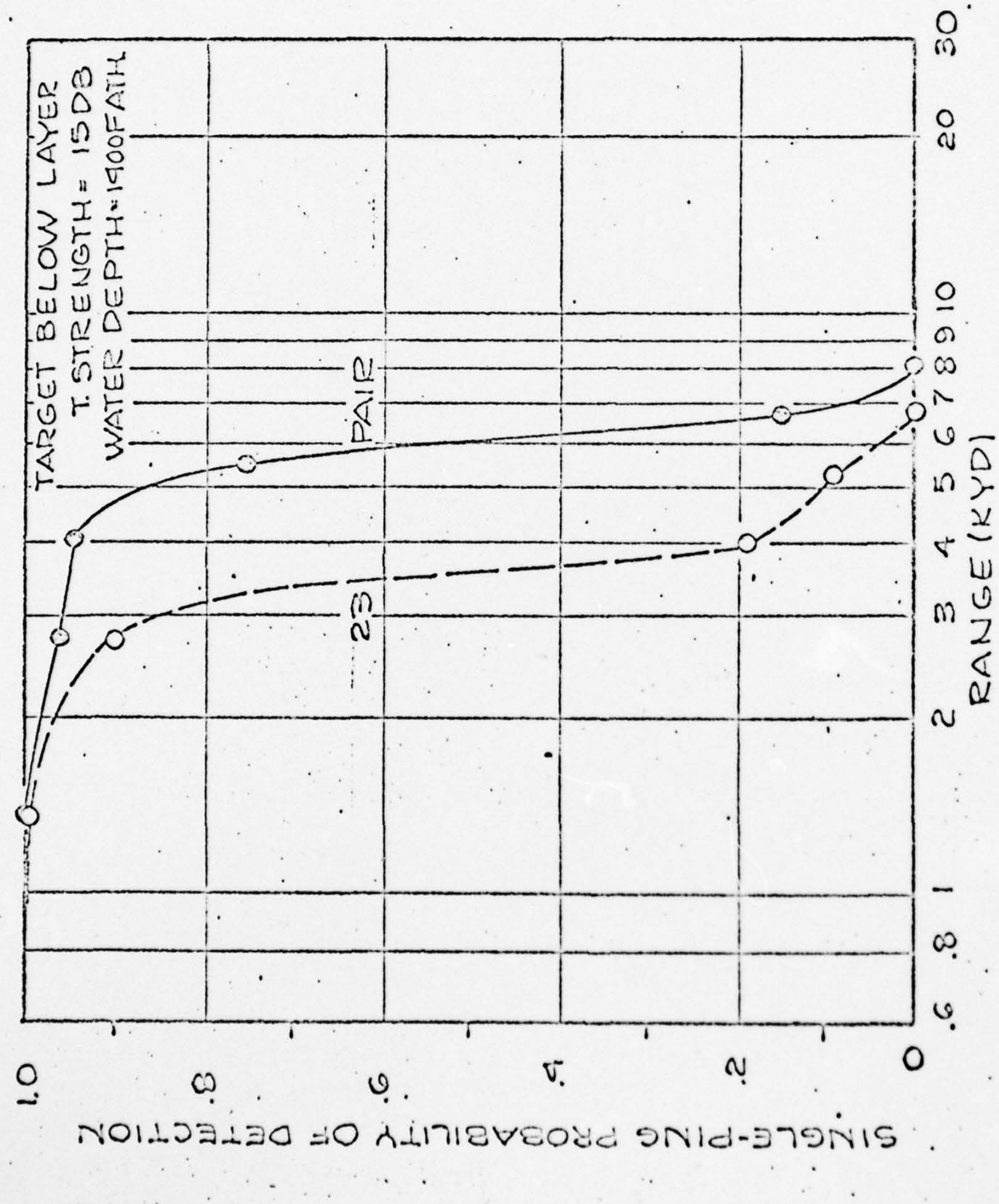

FIG. II (K) — CONSTANT ASPECT DETECTION PROBABILITY

DWG

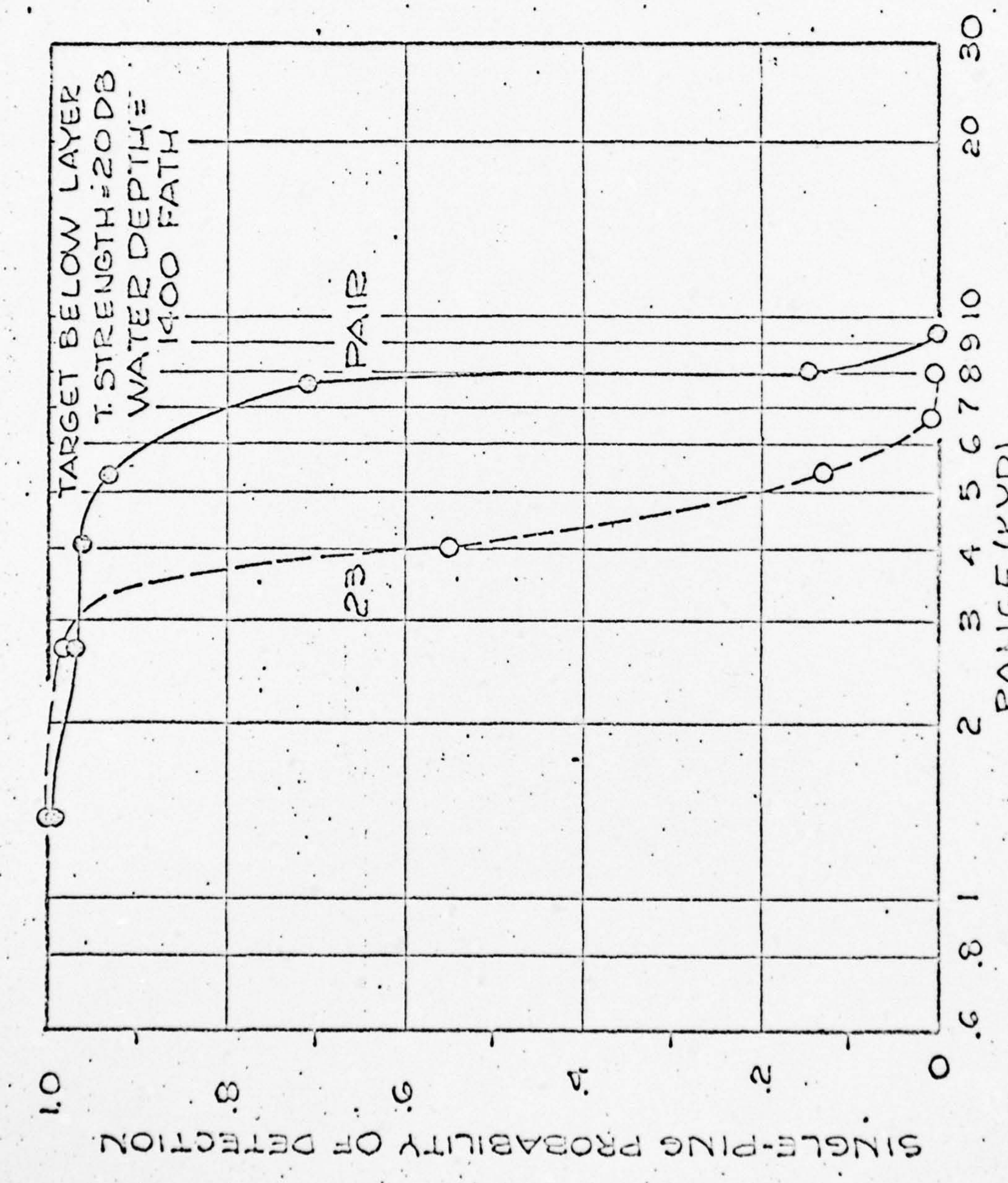

FIG. II (L) — CONSTANT ASPECT DETECTION PROBABILITY

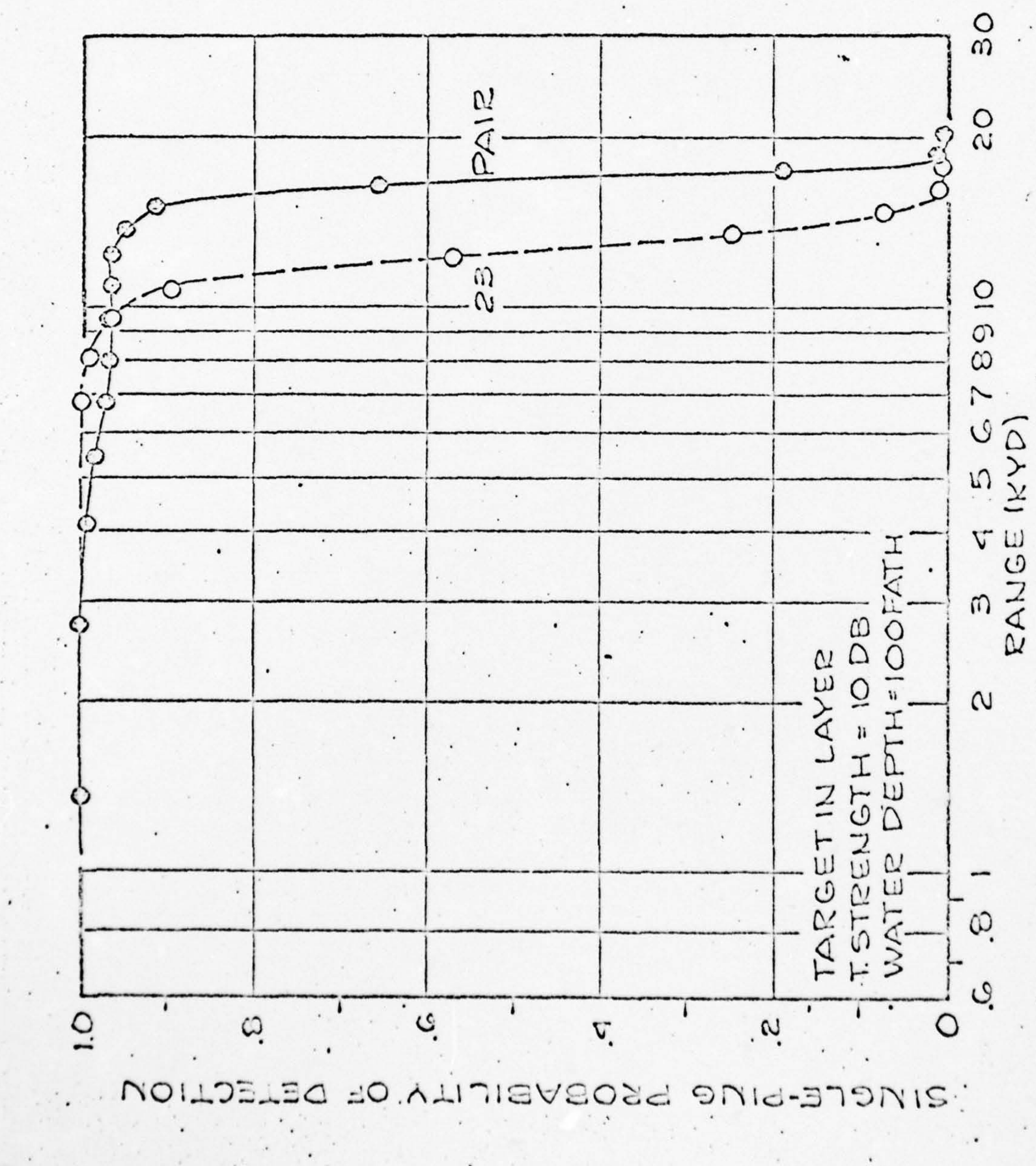

FIG. II (U)-CONSTANT ASPECT DETECTION PROBABILITY

DWG

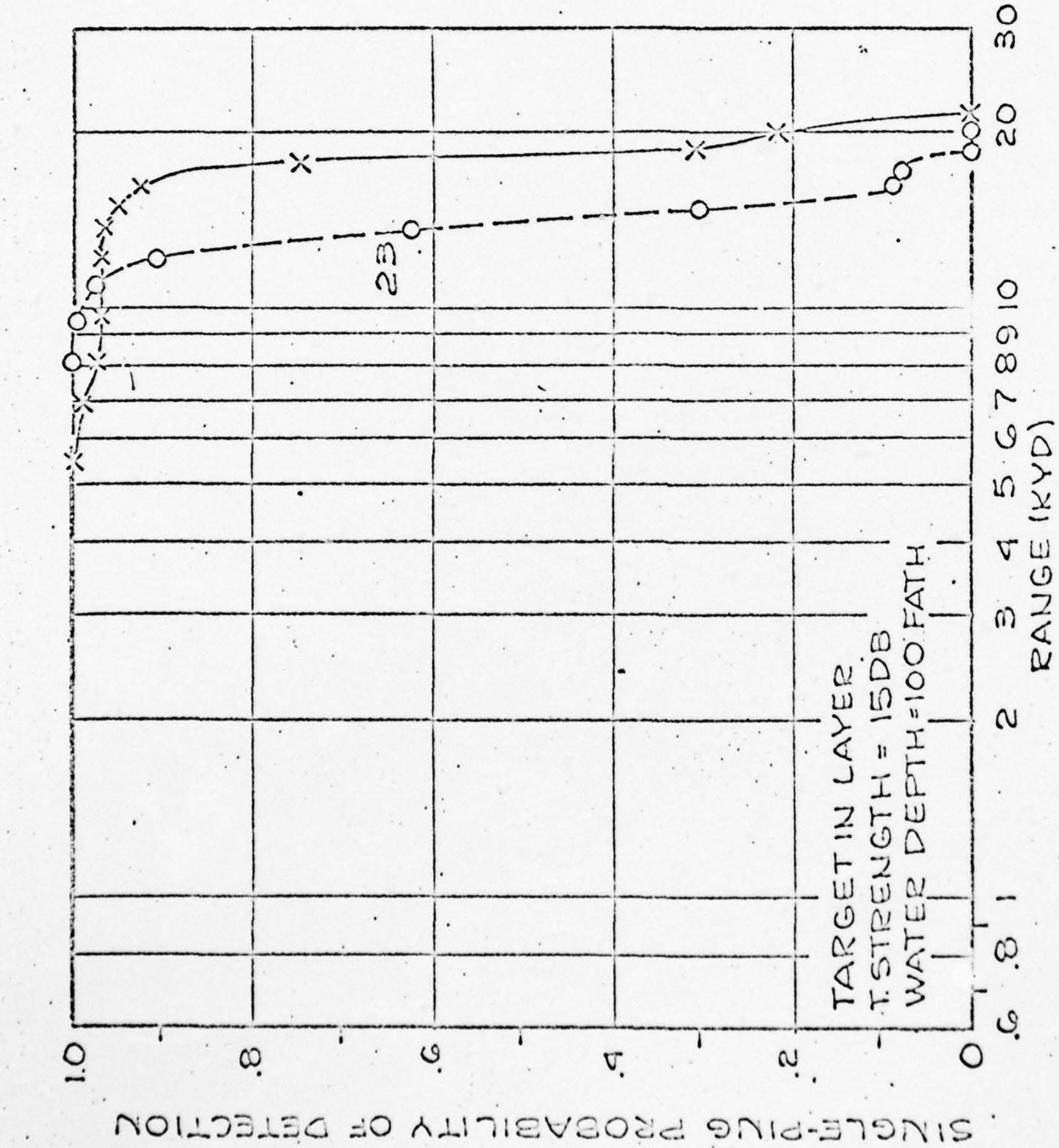

FIG. II (N)-CONSTANT ASPECT DETECTION PROBABILITY

 TRACOR, INC. AUSTIN, TEXAS DWG

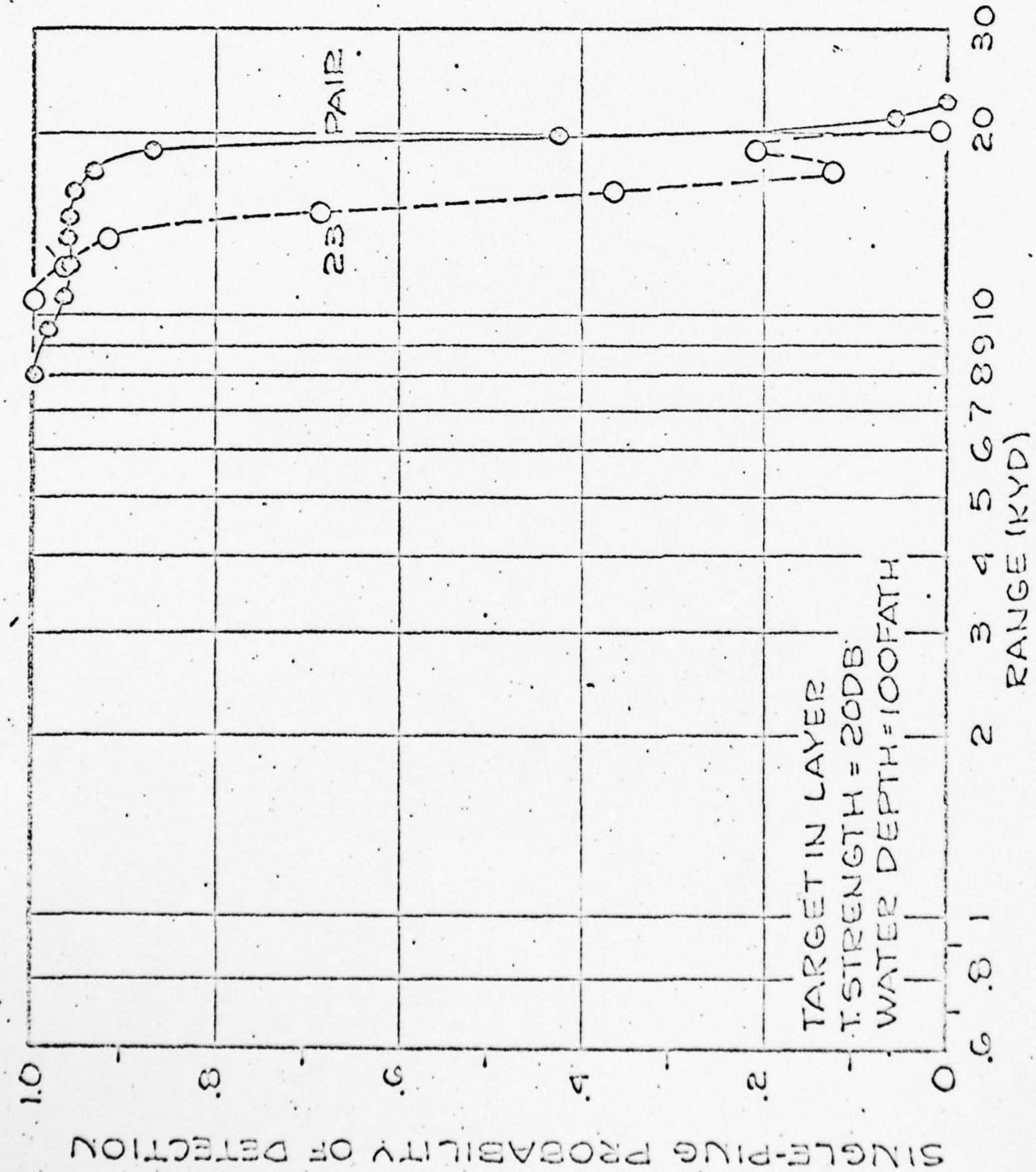

FIG. II (U)-CONSTANT ASPECT DETECTION PROBABILITY

DWG

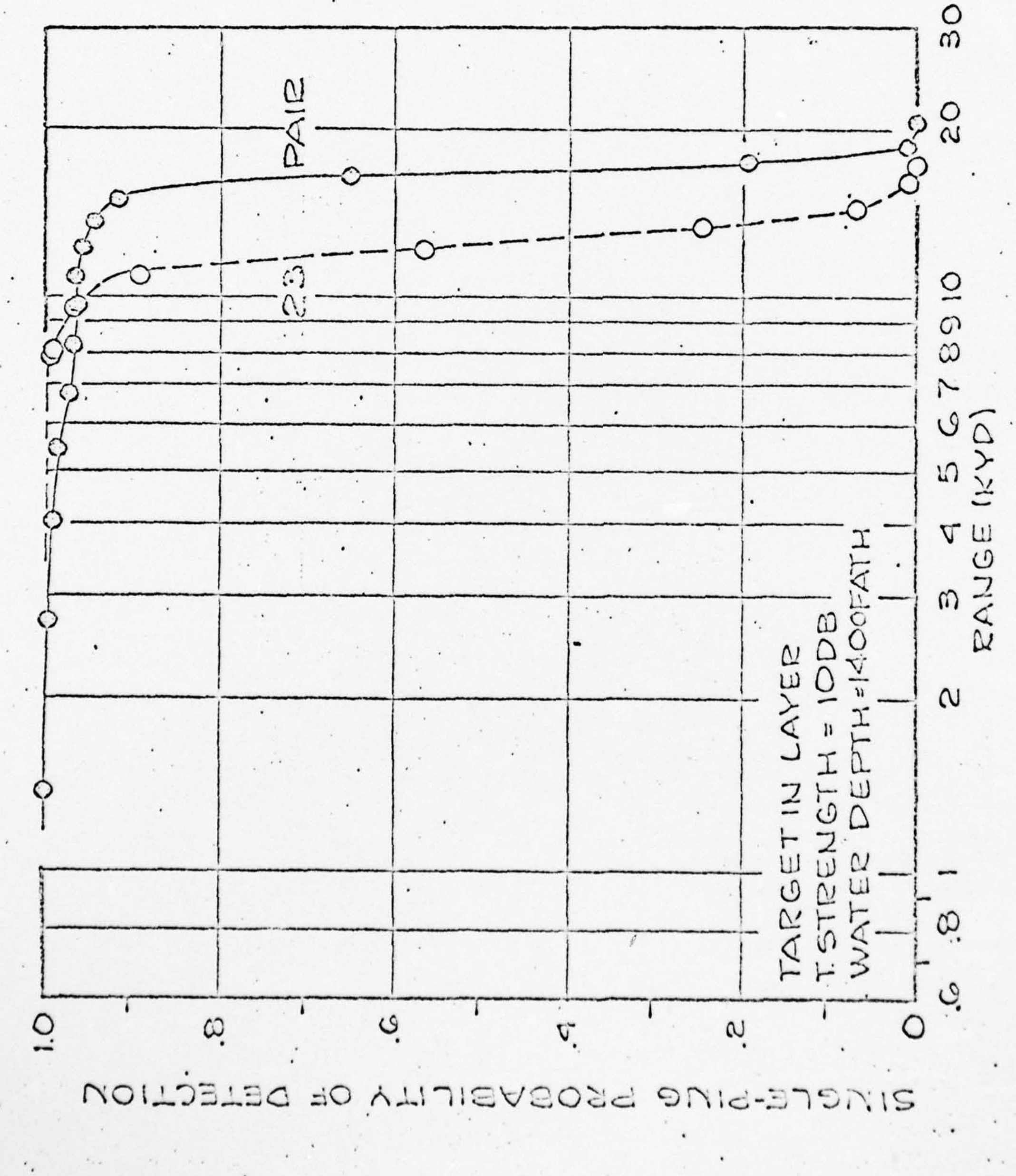

FIG. II (P)-CONSTANT ASPECT DETECTION PROBABILITY

DWG

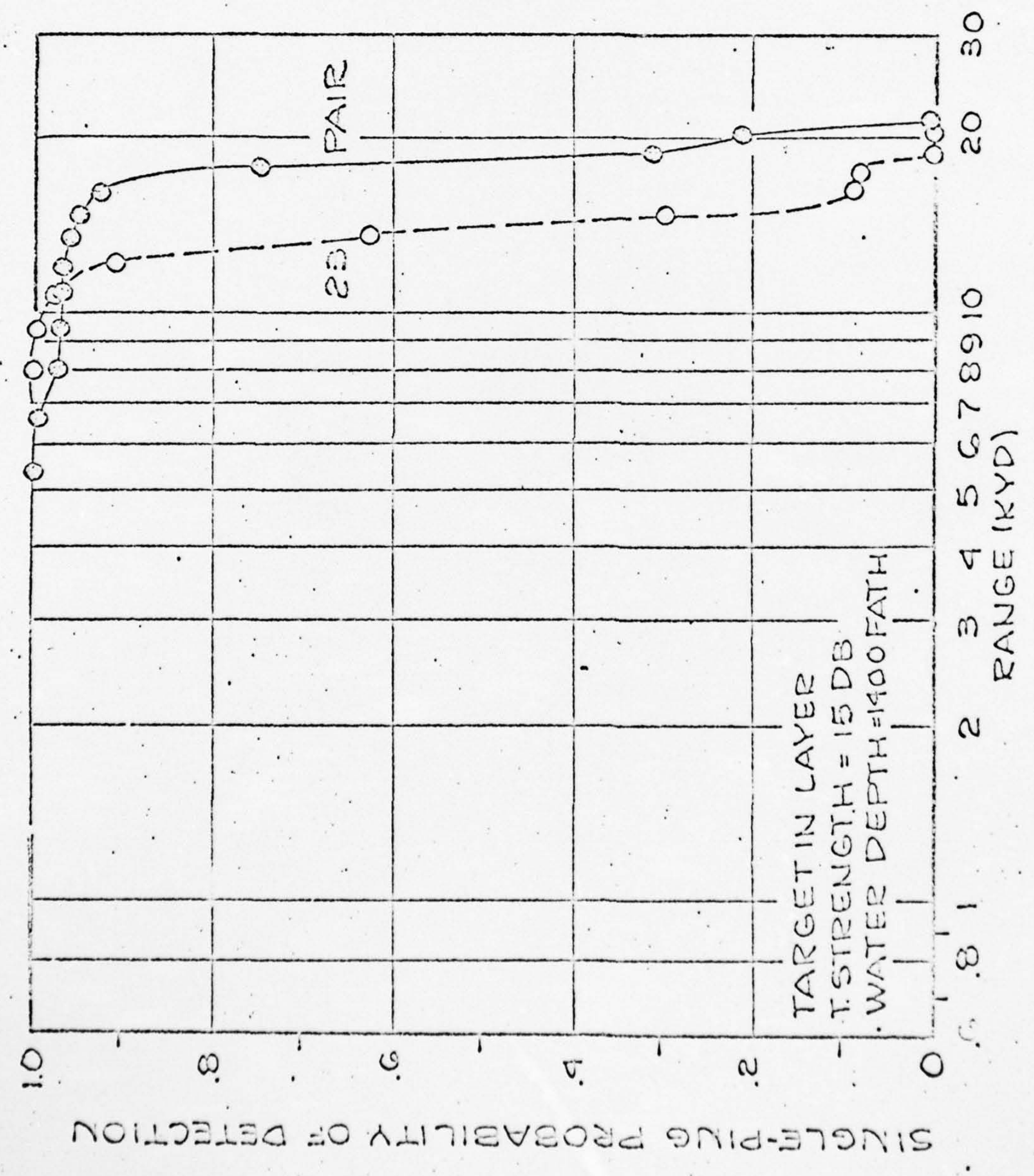

FIG. II (C)-CONSTANT ASPECT DETECTION PROBABILITY

DWG

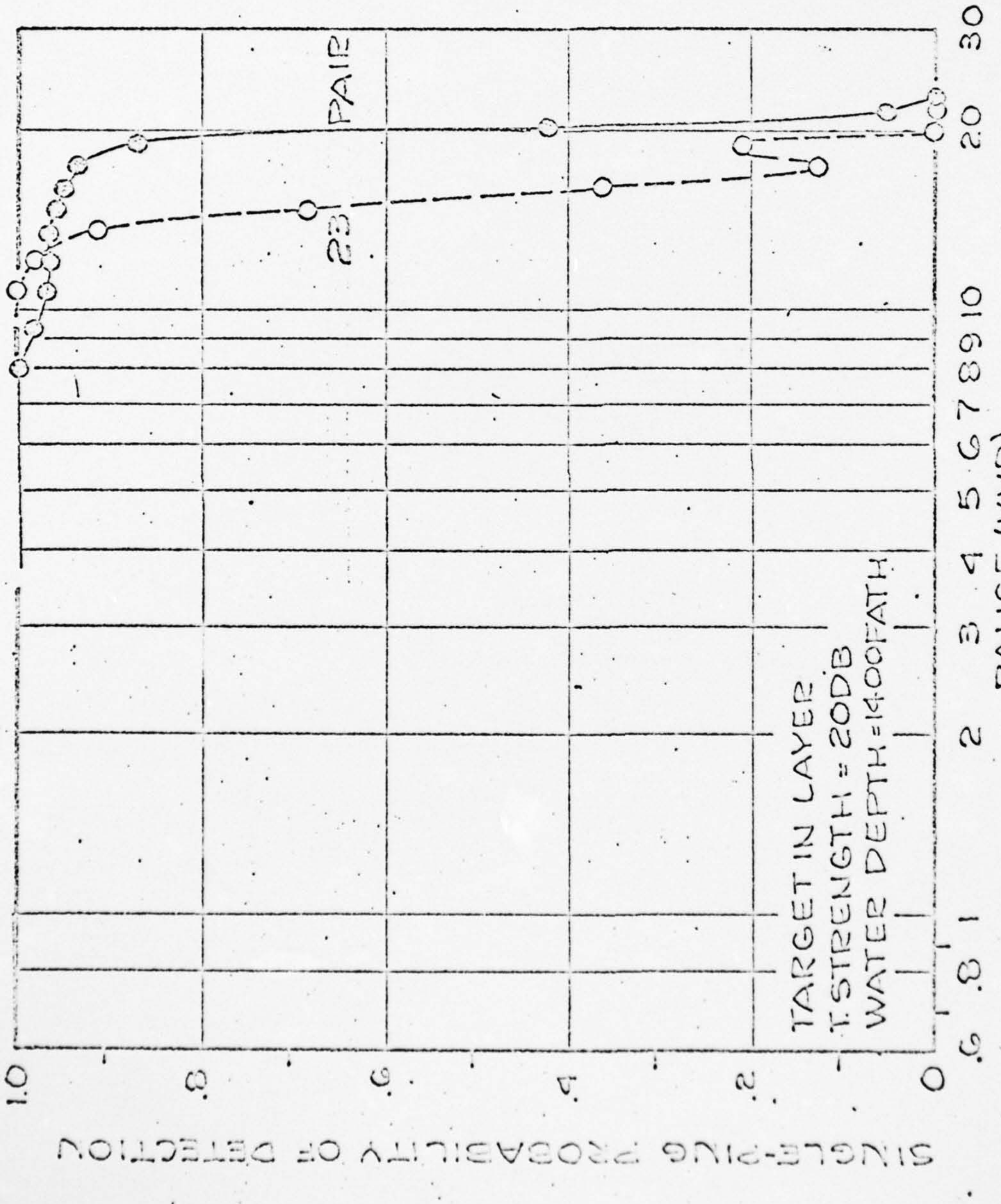

FIG. II (R)-CONSTANT ASPECT DETECTION PROBABILITY

AD-A037 038 NAVY ELECTRONICS LAB SAN DIEGO CALIF F/G 17/1
AN/SQS-23 (PAIR) SONAR LETTER REPORT.(U)
SEP 65 R D ISAAK
UNCLASSIFIED NEL-TM-1050 NL

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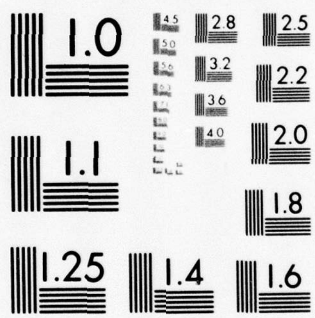

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

A comparison of the fleet log tabulation for below-the-layer targets with the performance model is shown in Figure II(s). The fleet log tabulation is shown as a discontinuous cumulative distribution representing the fraction of detections made at ranges less than each value shown on the horizontal axis. The three dashed curves, corresponding to three target strengths, indicates the expected AN/SQS-23 performance for below-the-layer targets obtained with the NEL performance modeling program. If it is assumed that the detections made at greatest range are made because target strength is high and the last targets detected at close range are those with the smallest target strength, a composite curve which is asymtotic to the 20 dB plot at long range and asymptotic to the 10 dB plot at short range can be drawn which would approximate the expected sonar performance.

Examination of Figure II(s) shows that there is good agreement between the fleet logs and the performance model at ranges less than 5 kyd. The discrepancy between the two curves at larger ranges probably indicates possible variation in layer conditions some distance from own ship, a few cases with still higher target strength, bottom bounce returns, or even logging errors. Below-layer performance beyond 6 kyd is certainly not an expected performance.

Similar results for above-layer targets are shown in Figure II(t). In this comparison the performance model predicts a rise in fraction of targets detected with approximately the same slope as the fleet log distribution. The predicted range at which the rise occurs is somewhat larger than the observed range. Whether this difference indicates difficulties in setting the display gain and maintaining brightness, operator alertness, or errors in the modeling cannot be stated at this time. It must be accepted that the modeling program predicts a somewhat optimistic performance for the AN/SQS-23.

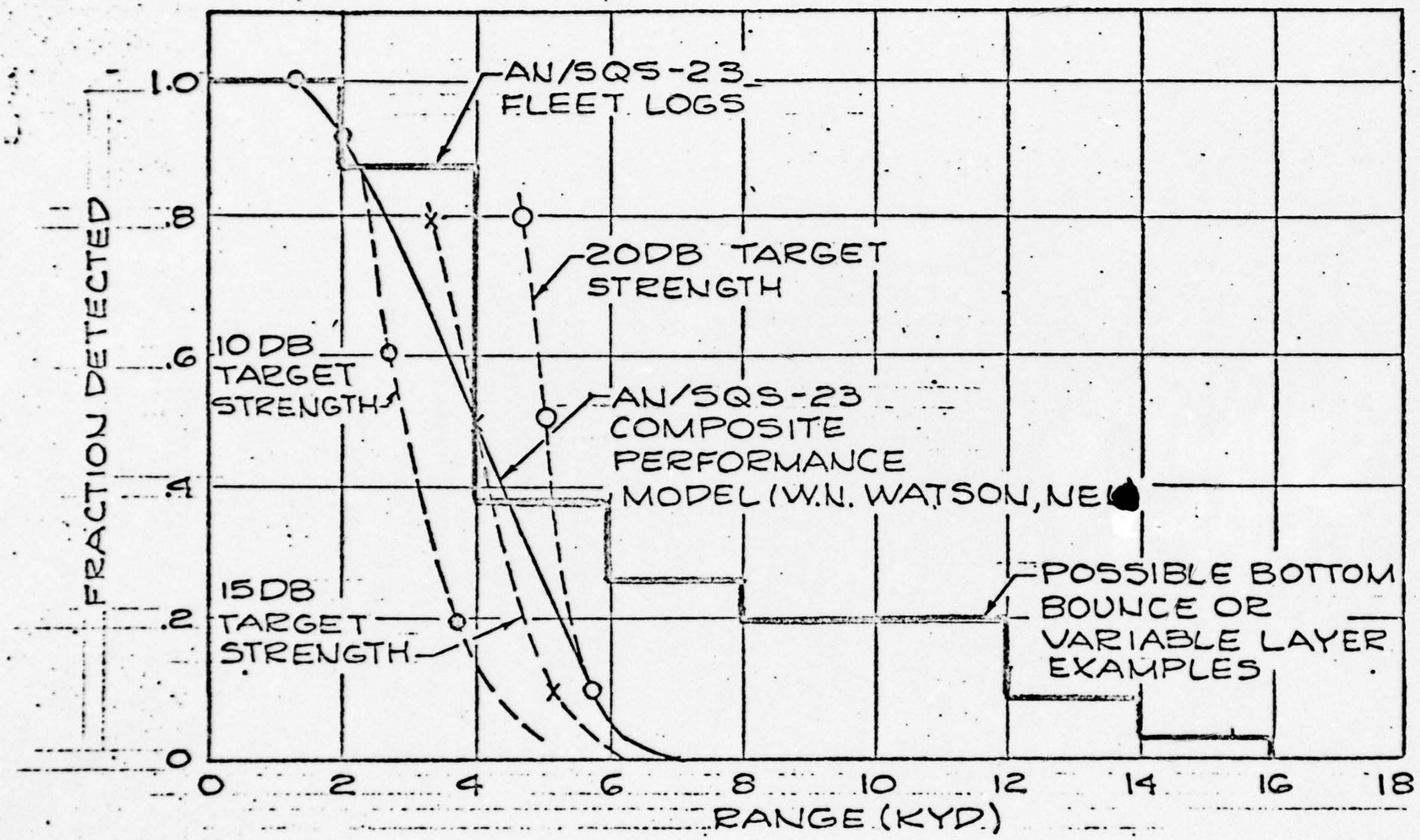

FIG. II (S) - DETECTION PROBABILITIES FOR BELOW-THE-LAYER TARGETS

DWG.

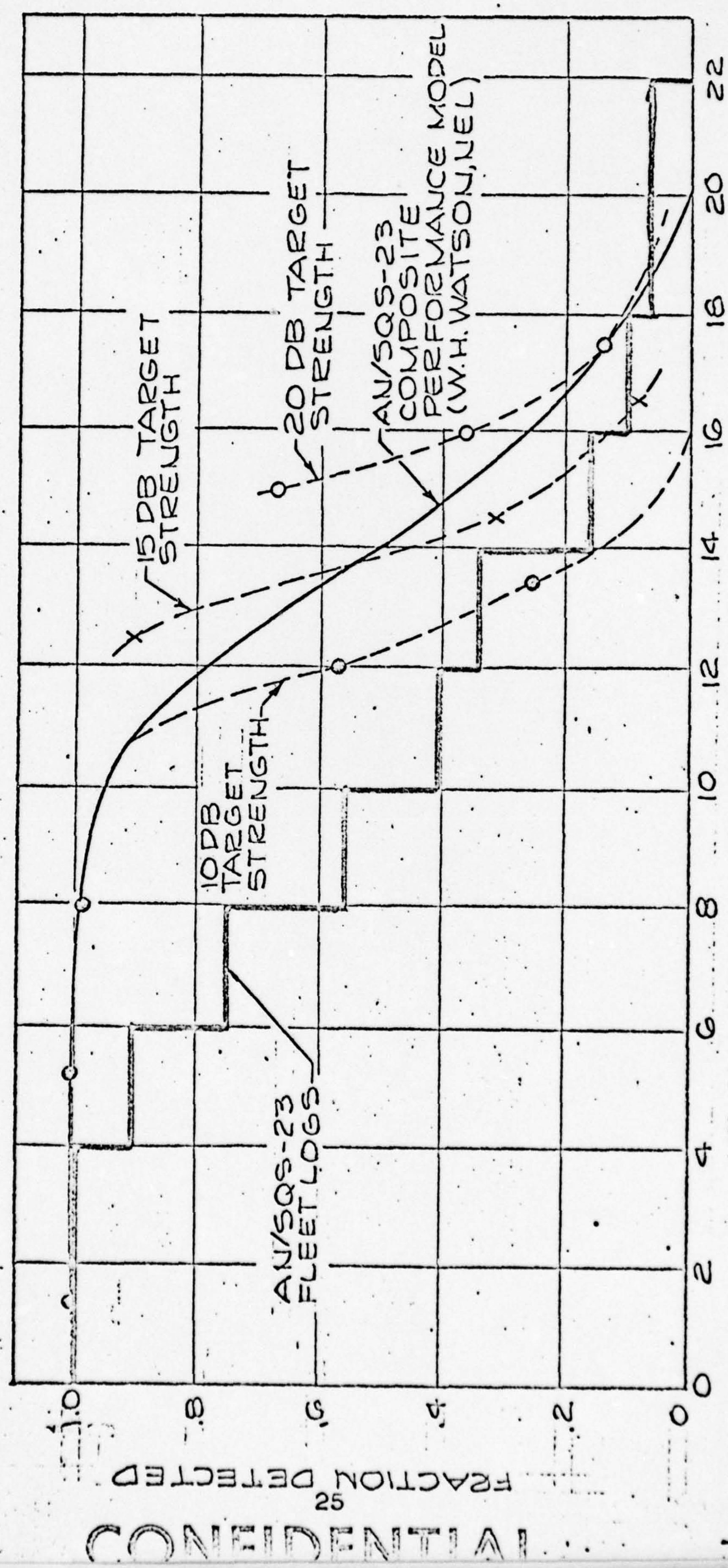

FIG. II (T) - DETECTION PROBABILITIES FOR IN-THE-LAYER TARGETS

1 DWG.

It should be pointed out that in all of the operational results selected for comparisons detections were made and no examples were included in which a target was present when no detection was made. The question of operator alertness is very important when examples of this type are included.

In summary of this comparison the following statements can be made:

(a) The parameters chosen to describe the performance of the AN/SQS-23 predict a performance slightly better than is observed in operational situations where detections are made. For in-layer targets the performance model predicts detection ranges about 40% higher than those observed; for below-layer targets the performance model predicts ranges essentially in agreement with those observed. The optimistic results possibly arise because of normalization difficulties in the operational SQS-23.

(b) Since the PAIR system parameters chosen for the prediction model were selected using the same principles, it must be assumed that the PAIR predicted results will have comparable validty, that is, will at most be slightly better than the performance which will be observed.

(c) In view of the statements (a) and (b) the ratios of detection ranges predicted by the PAIR and the AN/SQS-23 will be reliable numbers. The ratios of effective detection ranges are

$$\frac{\text{PAIR Det Range}}{\text{AN/SQS Det Range}} = \begin{cases} 1.3 & \text{for in-layer targets} \\ 1.8 & \text{for below-layer targets.} \end{cases}$$

(d) The minimum performance expected for the PAIR, based upon the detection range ratios in (c), for the cases listed in the fleet logs are indicated in Figures II(u) and II(v).

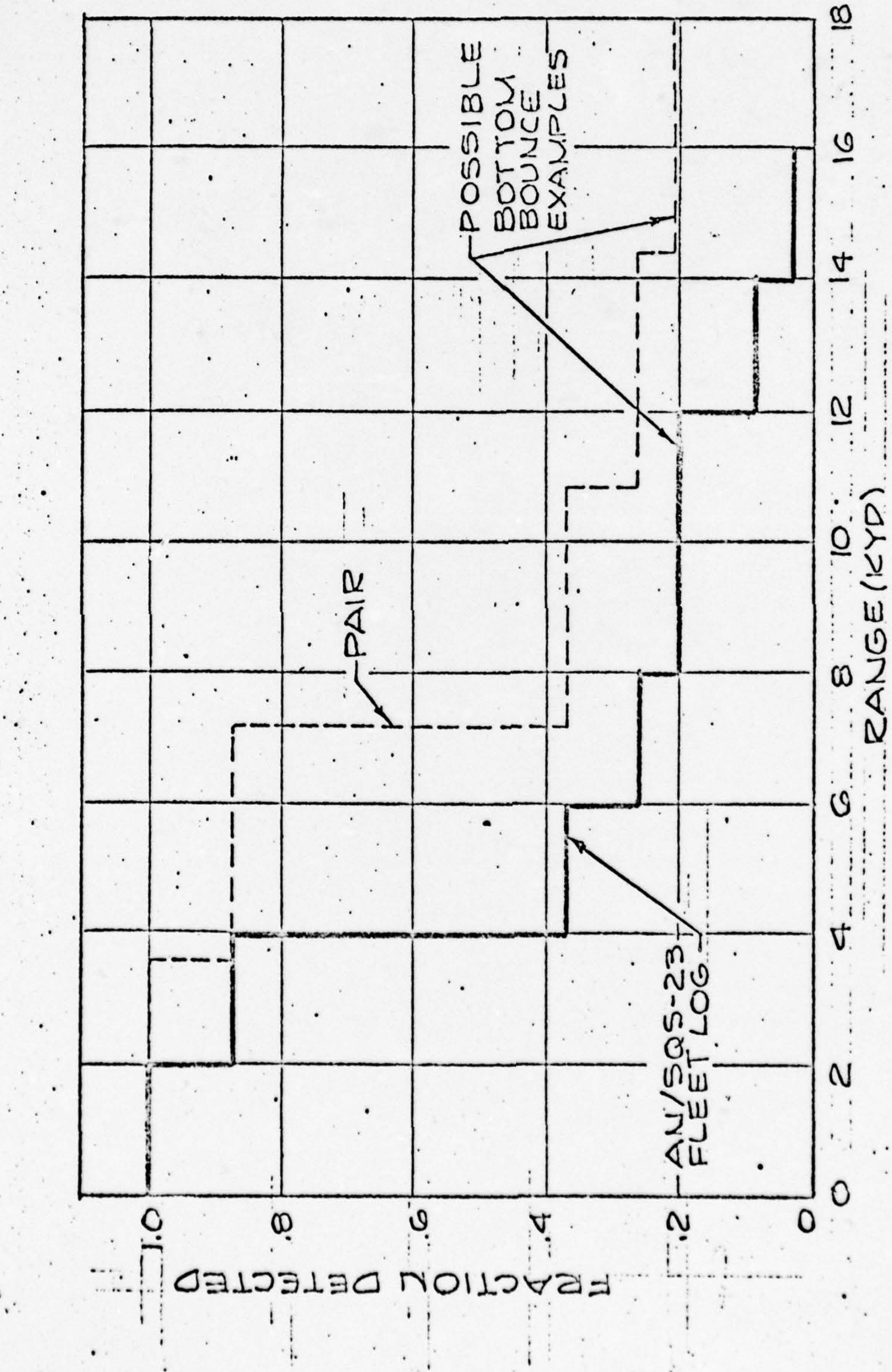

FIG. II (U) — PAIR MINIMUM PERFORMANCE ESTIMATED FOR BELOW-THE-LAYER TARGETS ON AN/SQS-23 DETECTIONS RECORDED IN FLEET LOGS

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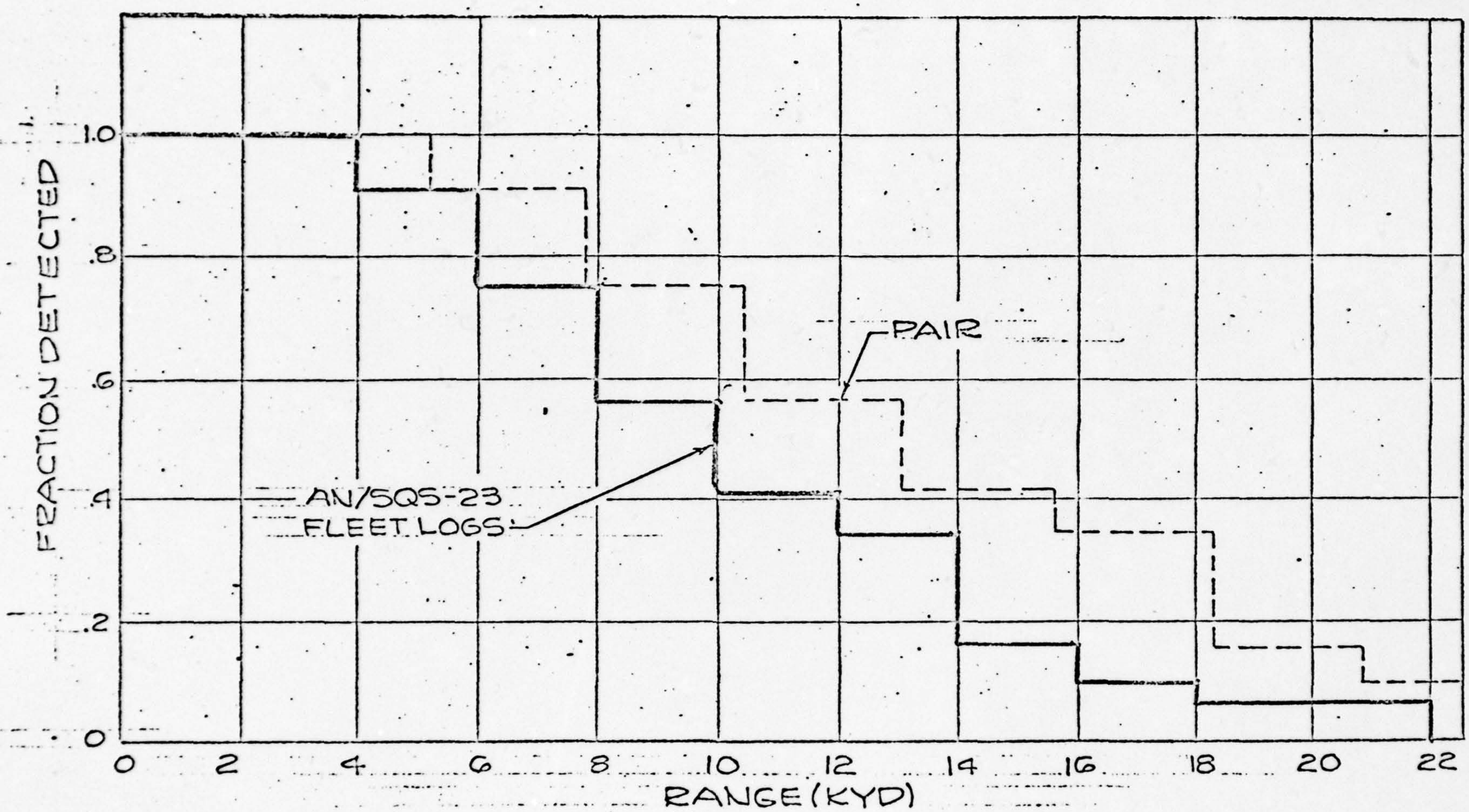

FIG. II (V)—PAIR MINIMUM PERFORMANCE ESTIMATED FOR IN-THE-LAYER TARGETS ON AN/SQS-23 DETECTIONS RECORDED IN FLEET LOGS.

1 - DWG.

(e) The PAIR maximum detection range predicted for (1) in-layer (100 ft layer) targets is 20 kyd; (2) below-layer targets is 8 kyd.

III. THE MUTUAL INTERFERENCE COMPARISON

Two situations have been considered in considering the mutual interference problem. One involves the ODT transmission and one involves the RDT. In the case of the ODT transmission the direct arrival occurs for a maximum of only 146 ms and is relatively unimportant in degrading either sonar performance. In this case it is the second ship reverberation which causes any observed interference. This interference will be referred to as rumble. The situation is quite different during RDT transmission because direct arrivals, when they occur, are observed for more than 4 seconds. As a result there is opportunity for degradation to occur over a 3.5 kyd range interval. Specific results for the shallow and deep water examples are illustrated.

The examples presented were prepared with the TRACOR reverberation model which includes the contributions of sidelobes. Minor differences between the results in this section and the preceding section will be found.

The 100 ft layer in 100 fathom water situation used in the preceding section is employed in the following. Figure III(a) shows a plot of target echo level (Target Strength = 15 dB) and reverberation level as a function of range on the display for the ODT with a source level of 120 dB. The echo level exceeds the reverberation level to a display range of about 4 kyd. Beyond this range the masking background is own ship noise. The 50% detection level for PAIR at a low clutter rate (~ 10 clutter points per display sweep) including ping-to-ping integration is dotted 2 dB below the masking level. The corresponding lowest level for 50% detection by the ideally normalized AN/SQS-23 is shown 2 dB above the masking level. A poorest performance level (upper limit) for the SQS-23 is marked 10 dB above the masking level. These levels represent the required echo levels so that detection can be accomplished 50% of the time at the specified clutter rates.

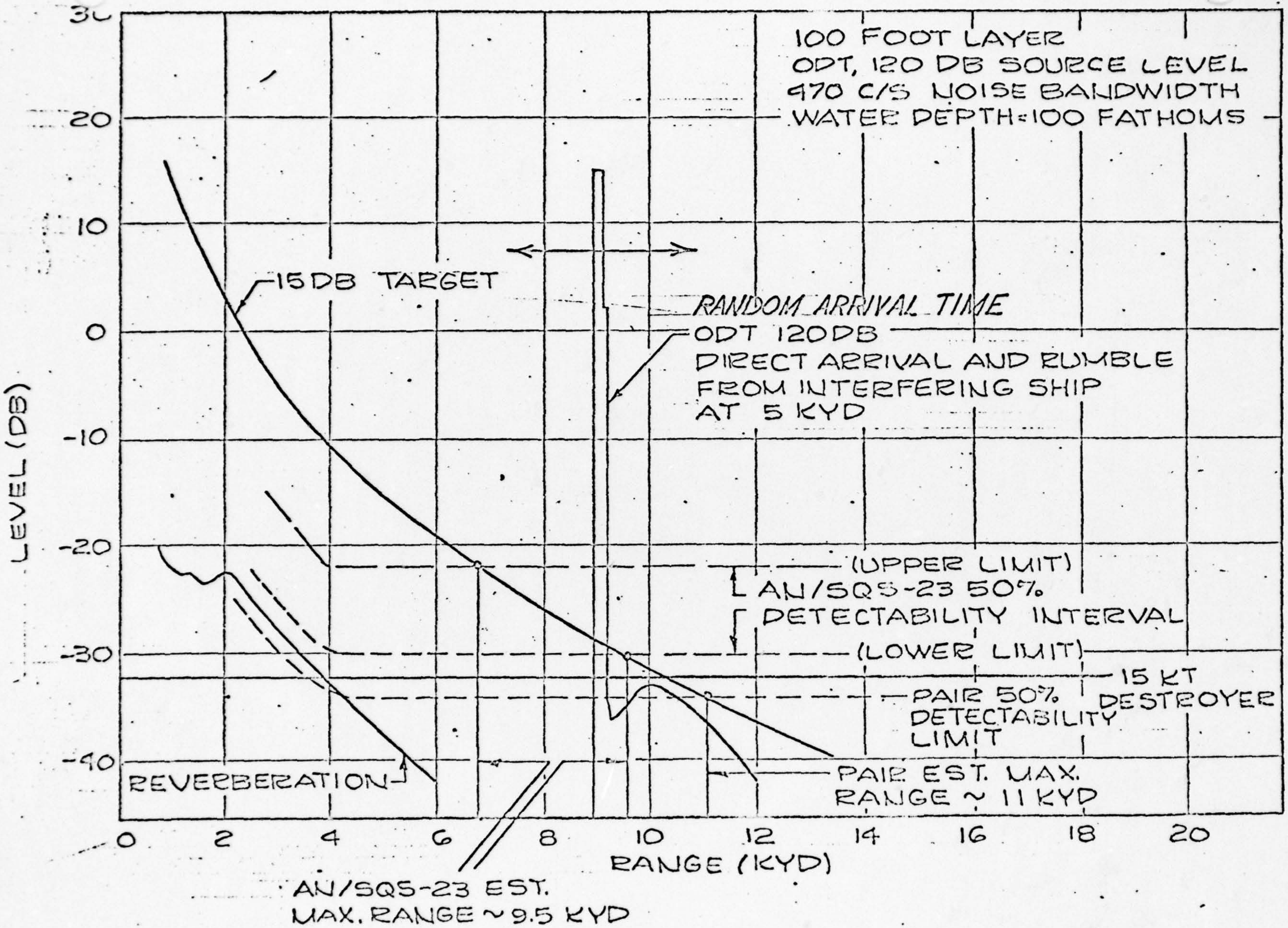

FIG. III (a) - ODT RANGE OF EFFECTIVENESS WITH MUTUAL INTERFERENCE

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The intersections of the 50% detection curves with the target echo level determine an estimate of the maximum range at which detection probability can be greater than or equal to 0.50 for each of the processors. These ranges are 6.7 to 9.5 kyd for the AN/SQS-23 and 11 kyd for the PAIR. In the absence of interference from other ships one would expect a PAIR ship to be capable of searching to a distance 1.2 to 1.6 times the corresponding distance to which a SQS-23 ship can search.

When a second ship is transmitting the same signal type (120 dB, ODT), an interfering signal arrives. The interference which is caused by a second ship at 5000 yards is also illustrated in Figure III(a). The large spike is the direct arrival and the direct reflection from the bottom. Thereafter the interference is rumble. The plot shows the interfering level in a receive beam not pointed at the interfering ship, a 20 dB reduction because of directivity pattern being assumed.

Except for the direct arrivals, no interference with either system can occur before the display range of 9 to 11 kyd. This is easily seen by imagining the rumble plot to slide back and forth across the plot while maintaining its level constant. When rumble is equal to the masking level without interference the combined masking level is 3 dB higher than either alone. Under this condition the dashed lines representing 50% detection levels must be raised 3 dB. This condition is almost exactly the situation shown in Figure III(a). If the 50% detection level is raised 3 dB for the AN/SQS-23 and the PAIR the maximum detection range for the SQS-23 lies between 5.8 and 8.2 kyd and the maximum detection range for the PAIR lies at 10 kyd. Both systems are degraded slightly.

The degradation of the PAIR is of primary interest in this discussion. The total useful range of PAIR without interference under the assumed water conditions is 11 kyd. The direct

arrival causes 144 ms of interference whenever it appears on the display. It blanks 110 yds of display in most bearings, approximately 1% of the useful 11 kyd region of the display. The rumble produces a more serious interference. When it arrives with its peak around 10.5 kyd it removes 1 kyd from the 11 kyd useful portion of the PAIR display. The probability that it will fall in this display region is also 1/11. The rumble reduces the useful PAIR range on the average no more than $1/121 \sim 1\%$.

It follows that the direct arrival plus the rumble cause, on the average, 2% of the 11 kyd useful to PAIR to be ineffective when the interfering ship is separated from own ship by 5 kyd.

Increasing the ship separation to 7.5 kyd reduces the rumble by 3 dB. It can be concluded that ships separated by more than 7.5 kyd are not degraded by anything but the direct arrival. This statement can also be made for increased water depth because the increased depth decreases the reverberation term not the noise level term. This comparison was made with both ships transmitting in the same band. When the ships transmit parallel slides, the direct arrivals mark the displays. When crossed slides are employed, the displays do not mark, but detection is prevented during the arrival. When the ships employ separate bands with as much as 60 dB isolation, rumble and direct arrival suppression is obtained; this additional rejection assures the absence of interference of any type for ships separated by as much as 7.5 kyd.

Figure III(b) shows similar relationships between the target and background levels for RDT, 135 dB source level in deep water. In this example the PAIR is effective out to 18 kyd; the AN/SQS-23 is effective to 14 to 17 kyd. The interfering arrivals from a second ship categorized as rumble behave very much like the rumble characteristics discussed in connection with Figure III(a) and will not be included here except to say that no trouble is experienced from it if ship separations exceed 7.5 kyd.

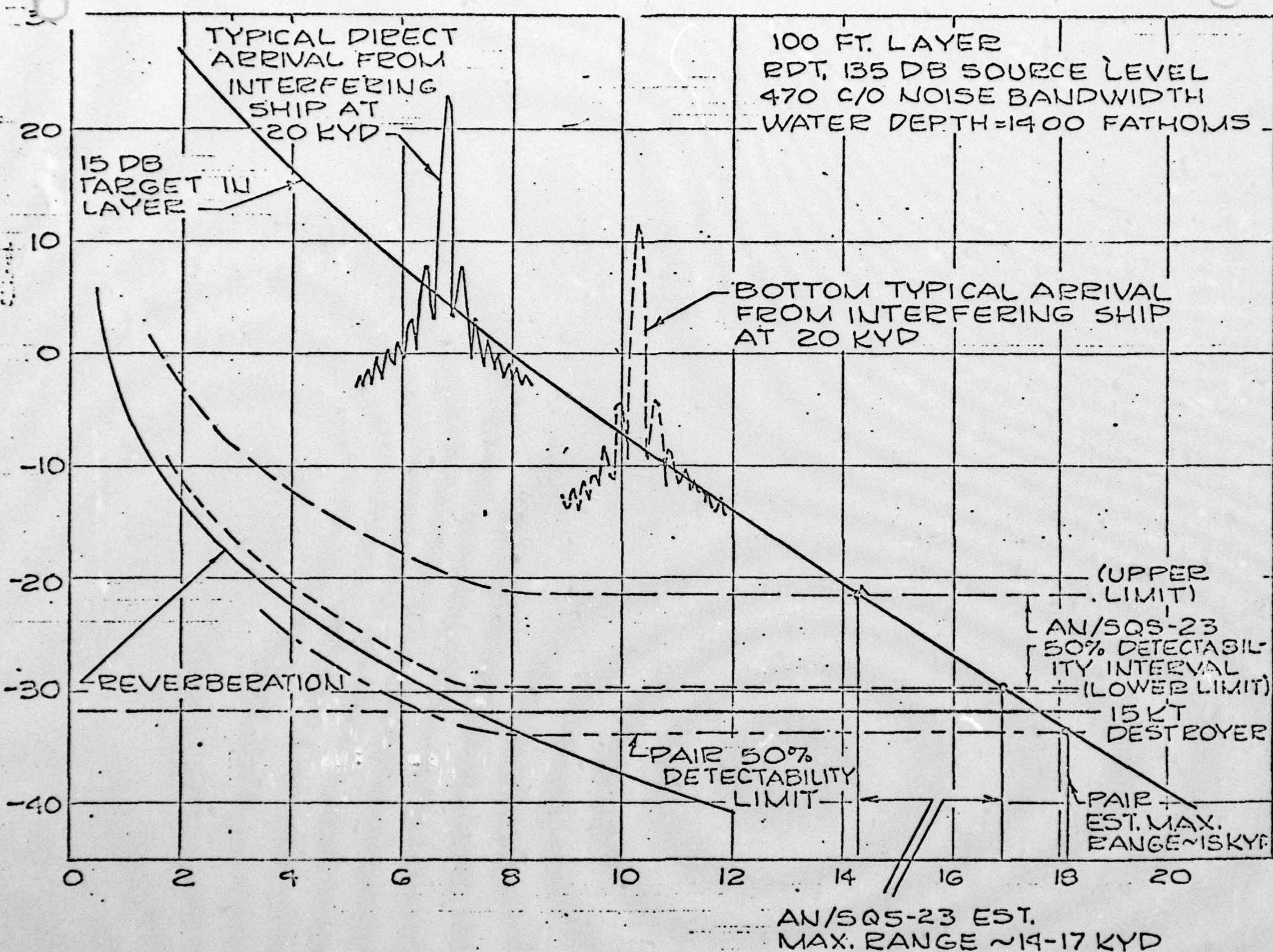

FIG. III (b) - RDT RANGE OF EFFECTIVENESS WITH MUTUAL INTERFERENCE

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A much more serious form of interference is caused by the RDT direct arrival from the interfering ship. As the rotating beam of the interfering ship sweeps by its beam pattern sets the interfering level at the own ship receiver. The duration of the interference is more than 4 sec so that during the worst interference a ring more than 3 kyd in width marks the display. The level of the direct arrival is shown as a beam pattern on the plot with the main beam arrival at 5.8 kyd on the display. The dashed pattern is a bottom bounce arrival shown with the main beam arrival at 10.3 kyd. Usually these arrivals are separated by much less than 4.5 kyd. They are shown in these positions to indicate the display range at which they cause interference. The levels shown are those caused by an interfering ship at 20 kyd in water having a depth of 1400 fathoms.

Clearly this interference makes the PAIR ineffective over somewhat over 4 kyd (the sum of the overlapped arrivals) of its 18 kyd effective range when the arrival occurs between 7 and 17 kyd on the display. The probability of arriving in this range is $10/(18 + 3) = 0.47$. In this fraction 18 kyd is the useful PAIR range, 3 is the range equivalent of the own ship RDT time, and 10 is the length of range interval in which interference is serious. The fraction of effective range degraded is 4/18, 4 kyd out of 18 kyd. The fraction of useful range made ineffective on the average per interfering ship is no more than

$$0.47 \left(\frac{4}{18}\right) = .10 \quad .$$

Silent sectors do no more than remove the central peak from each pattern and can therefore provide little relief from the interference. The use of crossed slides will remove the display marking but no detections will be made during the

time of the interference. Again the best measure against the interference is an adjacent transmission band with at least 60 dB of isolation.

By way of summary the following statements are made.

(a) ODT direct arrival degrades the PAIR on the average 1% of the time for ship separations to 20 kyd.

(b) ODT rumble does not degrade PAIR for ship separations beyond 7.5 kyd.

(c) RDT direct arrival from a single ship removes 10% of the useful PAIR display on the average with a ship separation of 20 kyd.

(d) Silent sectors do very little to aid the mutual interference problem.

(e) Crossed slides prevent marking of the display but do not prevent interference with detection.

(f) An adjacent transmission band with 60 dB of isolation is the most effective measure for preventing mutual interference.

IV. REQUIRED SHIP SPACINGS

(a) Mutual Interference Absent

Table I of Section II shows that the spacings of AN/SQS-23 ships along a line must be 5.6 kyd to provide a high probability that no submarine can slip by the line below the layer. Figure IV(a) shows such a line of five ships sweeping an area about 28 kyd across. Figure IV(b) shows a similar situation with PAIR ships spaced at 10.4 kyd. Three PAIR ships sweep an area 31.2 kyd in width with the same effectiveness.

It will be noticed that there is a distinct advantage with the PAIR ships. This relatively great advantage arises because of its relatively greater performance effectiveness for below-layer targets. When ships (PAIR or AN/SQS-23) are spaced to detect all the below layer targets, the above-layer targets are detected with ease.

(b) When mutual interference is introduced into this picture there is little degradation of the PAIR system.

In the deployment shown in Figure IV(b), adjacent PAIR ships utilize adjacent transmission bands, hence see no interference. The interfering ships are the alternate ones, separated by 20.8 kyd. If crossed slides are used there will be no clutter on the display, but 10% of the displays of these alternate ships will show no targets on the average. The nearest ship which can mark the display of a particular ship will be 41.6 kyd away and it can interfere with significantly less than 10% of the display. It is therefore safe to say that the effectiveness of a PAIR ship will be reduced at most 10% with this spacing.

Since the SQS-23 is also subject to interference it is also expected to be degraded significantly. Even with three

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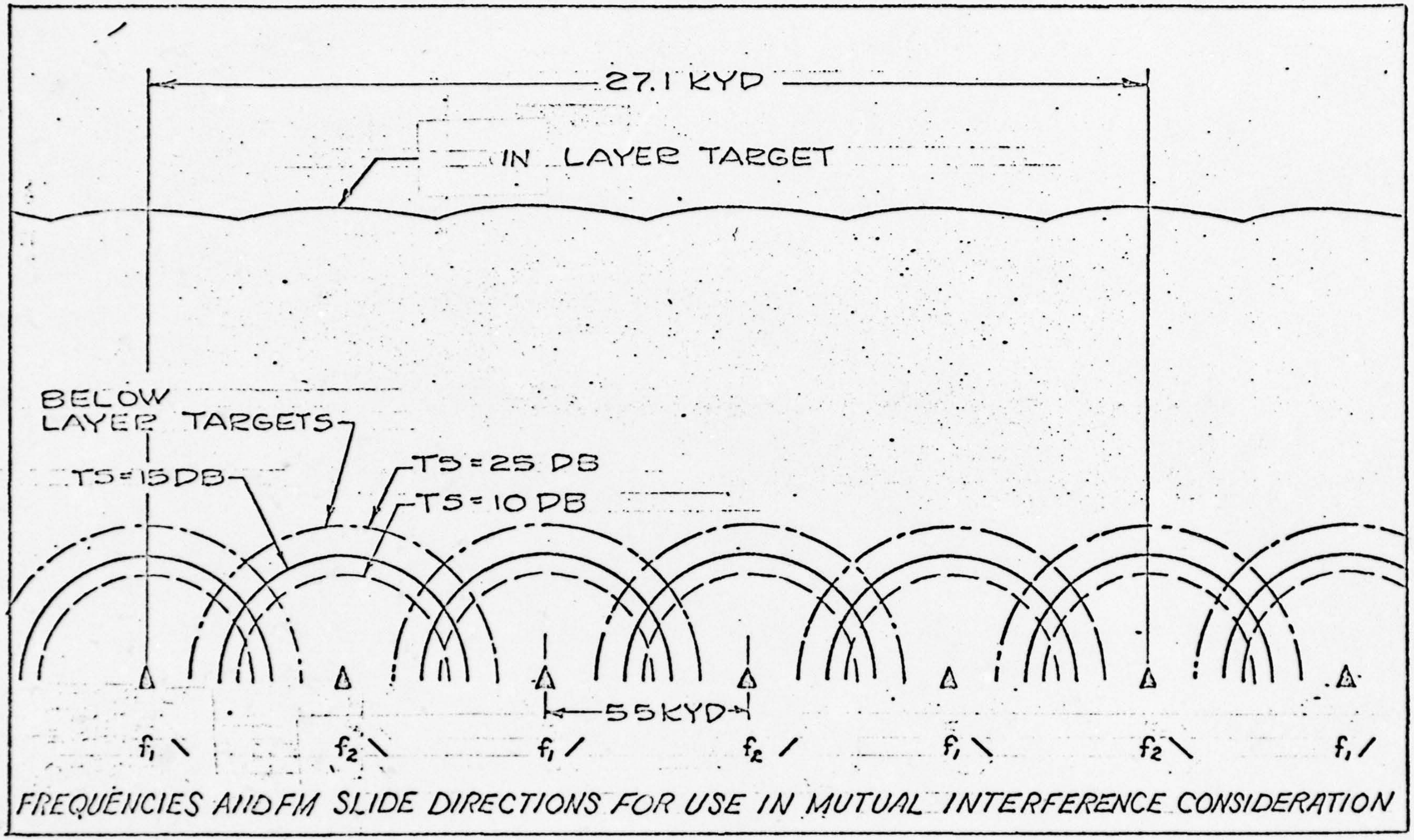

FIG. IV(a). -PREDICTED PERFORMANCE OF THE SQS-23

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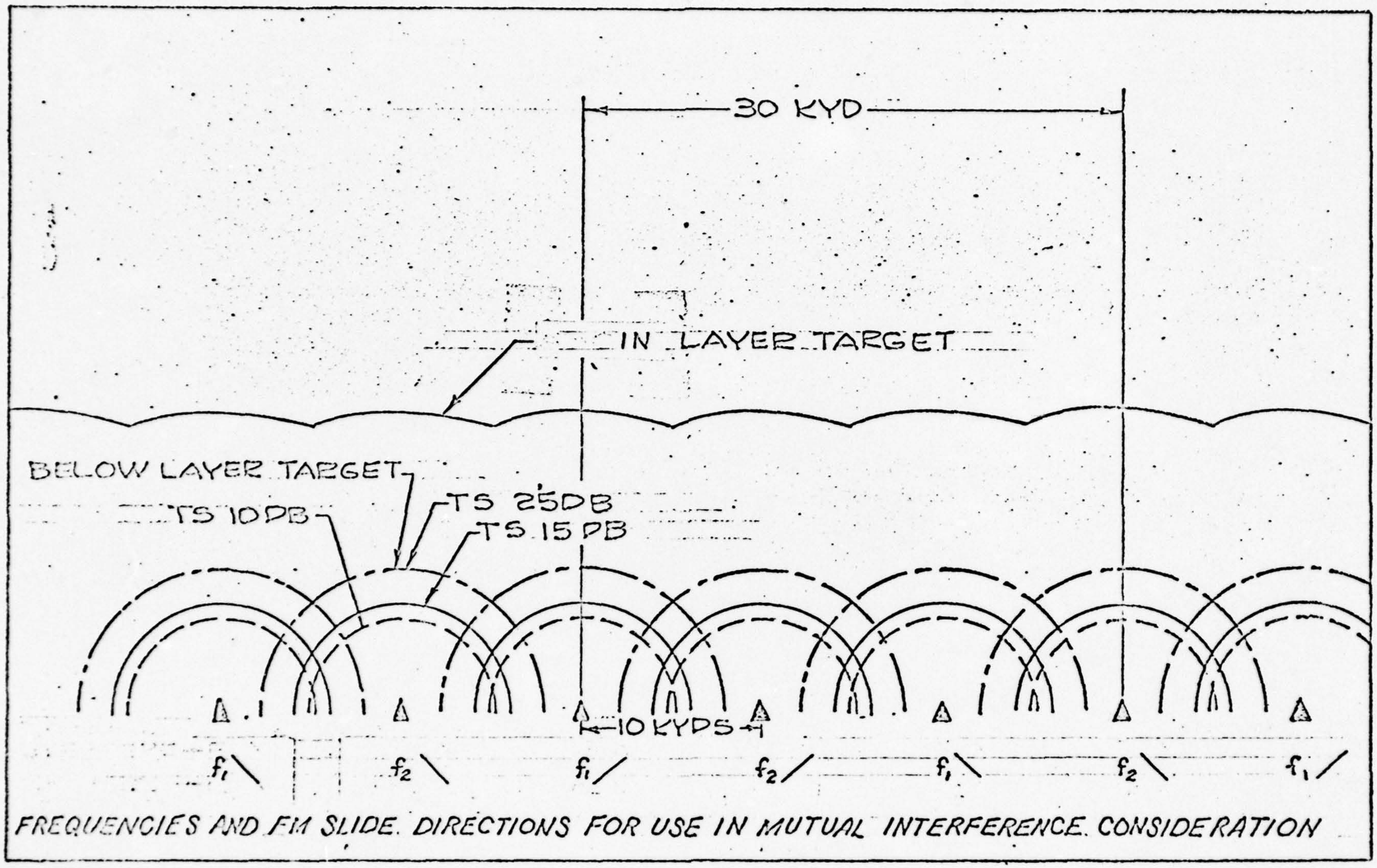

FIG. IV (b) - PREDICTED PERFORMANCE OF PAIR

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isolated transmission bands, the nearest interfering and marking signal comes from a ship 16.8 kyd away so the situation seems a little worse than for the PAIR.

The interference models studied thus far have assumed that RDT interferes with RDT and ODT interferes with ODT It is true the ODT will cause no trouble with the RDT cases. The reverse is 15 dB worse than the worst RDT case described when the RDT arrival falls on the ODT searchscale. For the case of ODT, 5 kyd search followed by RDT 20 kyd search on both ships, not quite synchronous, the 4 sec RDT of each ship marches through the ODT and RDT display of the other. The interference with the RDT has already been considered.

The interference with the ODT display is .67% when it occurs. Its probability of occurrence is $4/(6 + 24) = .13$. The denominator is the sum of the ODT search time and the transmit and listen in the 20 kyd search. The decrease in effectiveness is therefore $(.67)(.13) \cong 0.1\%$.

There is one other way of reducing interference and that is to synchronize transmission times so that transmission from a particular ship and one set of interfering transmission occur at the same time. This is not a possible solution for both ships of the interfering pair except in fortuitous circumstances. It would be useful to a ship near the center of a line of ships who was bothered by the alternate ships on both sides because it could remove one of the interferences completely.

This section may be summarized briefly with two statements:

(1) When ships are spaced on a line such that the probability of sweeping below the layer targets from the area generated by the line exceeds 50%, nearly half as many PAIR ships are required as AN/SQS-23 ships.

(2) Mutual interference problems in searching with the PAIR ships equipped with two search transmission bands decrease the effective search range no more than 10%.

V. MODELING PARAMETERS AND ASSUMPTIONS

The list of parameters used in the various simulations is presented here. Each list or curve is headed by a Reference Number. The system parameters under Reference Number SP714-1 are for the PAIR System. The system parameters under Reference Number SP714-2 are for the AN/SQS-23; most parameter values are left blank in this list. Those parameters are the same as for the PAIR system, as is noted at the bottom of the page. Where a Reference Number appears for a parameter value, the parameter is a variable which is given as a curve. The curve is given, in tabulated form, under the Reference Number listed in lieu of a constant value. Tabulated curves included processing and display gain, transducer lobe patterns, the ship self-noise versus velocity, the submarine target strength versus aspect, and the velocity profiles. The transmitted horizontal beam pattern is not given, as in either RDT or ODT the lobe pattern is not significant for detection purposes. Therefore, the directivity index was used, and was sufficient to provide a correct reverberation simulation model. The transmitted beam pattern was used in the RDT mutual interference simulation, and the transmitted horizontal beam pattern is essentially identical to the receive horizontal beam pattern.

Two environmental profiles are used, one for 600 feet bottom depth and one for 8400 feet bottom depth. Only the 8400 foot profile is given, because the 600 foot profile was identical except for the bottom depth, and the same curve was given the computer for both conditions. The bottom depth input was separate and was all that was required by the program to correctly model the environment.

NEL EM-F3

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SONAR SYSTEM PROFILE

[SONA]R SYSTEM PROFILE REFERENCE NUMBER SP714-1

SYMBOL	DESCRIPTION	INPUT VALUE
F	OPERATING FREQUENCY (KC)	4.5
I	SOURCE LEVEL DB/1μb^2	135
AGP	PROCESSING GAIN FUNCTION	GP714-1
AGD	DISPLAY GAIN FUNCTION	GD714-1
CKTL	PROCESSING CIRCUIT LOSS	0
RDA	SINGLE PING OUTPUT RECOGNITION DIFFERENTIAL	12.8
GI	IMAGE GAIN	0
DELFR	INPUT BANDWIDTH CPS	470
DIR	RECEIVING DIRECTIVITY INDEX	23
DELTHETAR	RECEIVING AZIMUTHAL MAIN LOBE BEAM WIDTH (3DB)	10
TIMEBP	TIME BETWEEN PINGS	2
VBEAMR	RECEIVING VERTICAL LOBE SHAPE	VBR714-1
HBEAMR	RECEIVING AZIMUTHAL LOBE SHAPE	HBR714-1
VBEAMX	TRANSMIT VERTICAL LOBE SHAPE	VBX714-1
HBEAMX	TRANSMIT AZIMUTHAL LOBE SHAPE	HB X 714-1
SIGMA	STANDARD DEVIATION OF OUTPUT SIGNAL EXCESS	5
TPULSE	TRANSMITTED PULSE LENGTH (SEC)	.0024
FNSF	SHIP NOISE FUNCTION	NS714-1
TGSTR	TARGET STRENGTH FUNCTION	TS714-1

* All other Parameters identical to

DATE ______________________

SONAR SYSTEM PROFILE

R SYSTEM PROFILE REFERENCE NUMBER SP714-2*

SYMBOL	DESCRIPTION	INPUT VALUE
F	OPERATING FREQUENCY (KC)	
I	SOURCE LEVEL DB/1μb^2	
AGP	PROCESSING GAIN FUNCTION	0
AGD	DISPLAY GAIN FUNCTION	2
CKTL	PROCESSING CIRCUIT LOSS	
RDA	SINGLE PING OUTPUT RECOGNITION DIFFERENTIAL	12
GI	IMAGE GAIN	
DELFR	INPUT BANDWIDTH CPS	
DIR	RECEIVING DIRECTIVITY INDEX	
DELTHETAR	RECEIVING AZIMUTHAL MAIN LOBE BEAM WIDTH (3DB)	
TIMEBP	TIME BETWEEN PINGS	
VBEAMR	RECEIVING VERTICAL LOBE SHAPE	
HBEAMR	RECEIVING AZIMUTHAL LOBE SHAPE	
VBEAMX	TRANSMIT VERTICAL LOBE SHAPE	
HBEAMX	TRANSMIT AZIMUTHAL LOBE SHAPE	
SIGMA	STANDARD DEVIATION OF OUTPUT SIGNAL EXCESS	
TPULSE	TRANSMITTED PULSE LENGTH (SEC)	
FNSF	SHIP NOISE FUNCTION	
TGSTR	TARGET STRENGTH FUNCTION	

* All other Parameters identical to SP714-1

DATE________________

ENVIRONMENTAL PROFILE

ENVIRONMENTAL PROFILE REFERENCE NUMBER EP714-1

SYMBOL	DESCRIPTION	INPUT VALUE
VELP	VELOCITY PROFILE FROM SURFACE TO BOTTOM	VP714-1
T	SURFACE WATER TEMPERATURE	60
ZL	LAYER DEPTH	100
CS	SOUND VELOCITY AT SURFACE	4972.5
MUVL	VOLUME SCATTERING LEVEL IN LAYER	-100
GAMMAO	GRADIENT IN THE LAYER	.018
GAMMA1	GRADIENT BELOW THE LAYER	-.333
PORB	BOTTOM POROSITY (OR OTHER BOTTOM LOSS CLASSIFICATION)	.60
MUB	BOTTOM SCATTERING STRENGTH	-27
AMUV	VOLUME SCATTERING STRENGTH VS TIME OR RANGE	-100
ZBM	BOTTOM DEPTH	600
ZMUV	DEPTH OF SIGNIFICANT VOL. SCATTERING	100
LWA	WAVE HEIGHT	3
VWI	WIND VELOCITY	10
FNBI	BIOLOGICAL NOISE FUNCTION OF R	-100

* All other Parameters identical to

INPUT FUNCTION DATA SHEET

PAGE ____

FUNCTION: AGP

PERFORMANCE PREDICTION No GP714-1

S/N IN	GP	S/N IN	GP	S/N IN	GP
-7.	10.8				
-6.	11.6				
-5.	12.3				
-4.	13.0				
-3.	13.7				
-2.	14.3				
-1.	14.8				
0.	15.2				
1.	15.5				
2.	15.7				
3.	15.8				
4.	15.7				
5.	15.6				
6.	15.1				

DATE ____________

ENVIRONMENTAL PROFILE

ENVIRONMENTAL PROFILE REFERENCE NUMBER EP714-2*

SYMBOL	DESCRIPTION	INPUT VALUE
VELP	VELOCITY PROFILE FROM SURFACE TO BOTTOM	VP714-2
T	SURFACE WATER TEMPERATURE	
ZL	LAYER DEPTH	
CS	SOUND VELOCITY AT SURFACE	
MUVL	VOLUME SCATTERING LEVEL IN LAYER	
GAMMA0	GRADIENT IN THE LAYER	
GAMMA1	GRADIENT BELOW THE LAYER	
PORB	BOTTOM POROSITY (OR OTHER BOTTOM LOSS CLASSIFICATION)	
MUB	BOTTOM SCATTERING STRENGTH	
AMUV	VOLUME SCATTERING STRENGTH VS TIME OR RANGE	
ZBM	BOTTOM DEPTH	8400
ZMUV	DEPTH OF SIGNIFICANT VOL. SCATTERING	
LWA	WAVE HEIGHT	
VWI	WIND VELOCITY	
FNBI	BIOLOGICAL NOISE FUNCTION OF R	

* All other Parameters identical to EP714-1

VELOCITY PROFILE
IIND-NEL-TRIAL 731(50) (REV. 9-65)

DATE 11/3/65

PERFORMANCE PREDICTION REFERENCE NUMBER	VELOCITY PROFILE REFERENCE NUMBER
	VP714-2

BOTTOM DEPTH (FEET) ZBM	SURFACE VELOCITY (FPS) CS	BOTTOM VELOCITY (FPS) CBM
8900	4973	5000

POINT NO.	DEPTH METERS	DEPTH FEET	SOUND VELOCITY (FPS)	POINT NO.	DEPTH METERS	DEPTH FEET	SOUND VELOCITY (FPS)
1		0	4973	23			
2		100	4979.8	24			
3		400	4989	25			
4		920	4897.5	26			
5		1200	4915	27			
6		8900	5000	28			
7				29			
8				30			
9				31			
10				32			
11				33			
12				34			
13				35			
14				36			
15				37			
16				38			
17				39			
18				40			
19				41			
20				42			
				43			
22							

INPUT FUNCTION DATA SHEET PAGE ____

FUNCTION: AGD PERFORMANCE PREDICTION No GD714-1

S/N OUT	GD	S/N OUT	GD	S/N OUT	GD
-30.5	-18				
+ 9.5	2.2				
+11.	2.9				
13.5	3.7				
15.5	3.2				
17.5	2.				
29.5	- 4.				

INPUT FUNCTION DATA SHEET

PAGE ____

FUNCTION: VBEAMR

PERFORMANCE PREDICTION No VBR714-1

DEGREES	DBDOWN	DEGREES	DBDOWN	DEGREES	DBDOWN
0	0	57.5	20.5		
2.5	.8	60.0	21.		
5.0	2.1	62.5	22.		
7.5	5.0	65.0	23.5		
10.0	10.5	67.5	26		
12.5	20.0	70.	30.		
15.0	20.0	72.5	38.		
17.5	15.0	75.	50.		
20.0	13.0	77.5	45.		
22.5	14.0	80.	40.		
25.0	17.0	82.5	34.		
27.5	25.	85.	32.		
30.0	30.	87.5	31.5		
32.5	21.	90.	31.		
35.0	18.				
37.5	17.5				
40.0	19.				
42.5	22.				
45.0	28.				
47.5	40.				
50.0	27.				
52.5	22.5				
55.	21.				

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FUNCTION: HBEAMR PERFORMANCE PREDICTION No HBR714-1

DEGREES	DBDOWN	DEGREES	DBDOWN	DEGREES	DBDOWN
0.	0.	57.5	28.		
2.5	1.	60.0	29.		
5.	3.	62.5	31.		
7.5	7.5	65.	30.		
10.	18.5	67.5	31.		
12.5	26.	70.	32.		
15.	20.	72.5	31.		
17.5	23.	75.0	32.		
20.	40.	77.5	31.		
22.5	24.	80.	30.		
25.	22.	82.5	31.		
27.5	24.	85.	31.		
30.	30.	87.5	28.		
32.5	28.	90.	30.		
35.	26.				
37.5	25.				
40.0	27.				
42.5	29.				
45.	32.				
47.5	28.				
50.	28.				
52.5	27.				
55.	28.				

INPUT FUNCTION DATA SHEET

PAGE ____

FUNCTION: VBEAMX

PERFORMANCE PREDICTION No VBX714-1

DEGREES	DBDOWN	DEGREES	DBDOWN	DEGREES	DBDOWN
0.	0.	57.5	20.5		
2.5	.5	60.	21.		
5.	2.	62.5	22.		
7.5	5.	65.	23.5		
10.0	10.	67.5	26.		
12.5	20.	70.	30.		
15.	21.	72.5	38.		
17.5	14.5	75.	45.		
20.	13.	77.5	50.		
22.5	14.	80.	40.		
25.	17.5	82.5	34.		
27.5	25.	85.	32.5		
30.	33.	87.5	31.5		
32.5	21.	90.	31.		
35.	18.				
37.5	17.5				
40.	19.				
42.5	22.				
45.	28.				
47.5	50.				
50.	27.				
52.5	22.5				
55.	21.				

INPUT FUNCTION DATA SHEET

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FUNCTION: FNSF

PERFORMANCE PREDICTION No NS714-1

SPEED (KNOTS)	NS	SPEED	NS	SPEED	NS
3	-48				
8	-48				
12	-41				
16	-35				
20	-28				
24	-21				

INPUT FUNCTION DATA SHEET

PAGE ____

FUNCTION: TGTSTR

PERFORMANCE PREDICTION No TS714-1

A ANGLE	DB	A ANGLE	DB	A ANGLE	DB
0.	10.	150.	12.2		
5.	10.5	160.	14.		
15.	13.5	165.	14.6		
18.	14.4	170.	12.8		
20.	14.5	175.	11.		
22.	14.2	180.	10.2		
35.	11.2				
40.	10.8				
45.	10.5				
50.	10.8				
60.	12.2				
70.	15.4				
75.	12.8				
80.	19.6				
85.	21.2				
90.	21.8				
95.	20.8				
100.	18.2				
125.	11.5				
130.	11.1				
135.	11.				
140.	11.2				
145.	11.6				

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I. TASK NUMBER: 21

II. TASK TITLE: Performance and Operations Analysis

III. INVESTIGATOR(s): Dr. W. Watson, Dr. B. Brown, TRACOR

IV. CONCLUSIONS:

A. <u>Recommended Changes to the Specification</u>

None

B. <u>Suggested Improvements</u>

None

C. <u>Need for Continued Investigation</u>

In order to evaluate the effectiveness of the proposed SQS-23 (PAIR) System, a performance and operational analysis of both active and passive detection, tracking, and classification capabilities must be conducted in the light of various geographical and tactical conditions.

V. DISCUSSION

Work is in progress in this area but computer programming changes have been more extensive than anticipated, so no firm results are available at this time.

DOWNGRADED AT 3-YEAR INTERVALS
DECLASSIFIED AFTER 12 YEARS
DOD DIR 5200.10

Enclosure (21)

CONFIDENTIAL

I. TASK NUMBER: 22

II. TASK TITLE: Human Factors

III. INVESTIGATOR: D. C. Lookingbill

IV. CONCLUSIONS:

A. Recommended Changes to Specification

No major changes in the contract specification in regard to this task appear necessary.

B. Suggested Improvements

Several improvement could be made resulting in improved system performance or operation. These are summarized below and expanded upon in Part V.

1. Modification to the Display Console structure for ease of operation.

2. Rearrangement of controls and indicators for better performance.

3. Provision for mechanically tilting of the passive search paper recorder for track correlation.

4. Insure that the minimum audio frequency cutoff is 600 cps and not 1000 cycles as now shown in the display buttons.

5. Figures 6-1 and 6-2 which give the console layout are no longer correct and must be redrawn.

C. Need for Further Investigation

A review of the revised console and panel layout should be made at a later date.

V. DISCUSSION

A. Display Console

There is some concern that adequate treatment from the human factors standpoint has not been accorded the design of the display console. The bullnose or desk should be kept clear of all but the necessary controls. If any indicator or control is associated with a particular display, CRT or paper, it should be mounted on that display panel at the same viewing level as the display.

The desk should be flat rather than sloping. Care must be exercised to insure that penetrations through the desk panel is water tight against spilled fluids. The clue evaluator panel should slope and line up with the adjacent panels. The tactical range recorders are mounted far too high. If at all possible they should be lowered.

B. Control Grouping

Further thought must be given to control grouping once the final number and types of controls are selected. Space will have to be provided for the new mode selection switches which in turn will effect the present panel arrangement for the active mode. These controls should be grouped together with a form of key lighting to indicate quickly the present status. When any non-standard options are used the MODE light should so indicate this fact.

C. Trace Detectability

Trace detectability could be improved for those conditions where fairly consistant but marginal intensity traces are being laid down on the passive search paper recorders, if the operator had the capability of lining up the traces by viewing them edgewise along the paper. This form of

eyeball integration might be provided by mechanically tilting the paper recorders or hinging them at the top edge.

D. Passive Reception

The electronics associated with passive reception permits operation down to 600 cps for the low frequency end before filtering. For most operating conditions it has been found that significantly better audio information can be provided if the lower frequency limit is extended below 1000 cycles. Since this capability now exists in the PAIR system design, the point here is to insure that the take off point for audio listening be made ahead of any PADLOC bandpass filtering.

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I. TASK NUMBER: 23

II. TASK TITLE: Mechanical Design and Cooling

III. INVESTIGATOR(s): J. Reardon, R. L. Bedore (J. Lamb)

IV. CONCLUSIONS

A. Recommended Changes to the Specification

Change paragraph 3.4.2.1 to -- "The hydrophone shall withstand all vibrations and shocks incidental to its intended use in naval ships, including repeated subjection to a maximum impulse pressure of 3200 psi of 0.5 milliseconds duration as cause by underwater explosions, without physical, electrical, or acoustical damage or leakage of sea water".

B. Suggested Improvements

None

C. Need for Continued Investigation

None

V. DISCUSSION

In Section 3.4.2.1, the impulse shock strength specified does not give assurance that some other form of vibration, shock, or flexure could not cause damage. It is thus felt that the more general statement of the original preliminary draft of the specifications should be incorporated as stated in IV.A. above.

It is likely that the graphic recorder specified in 3.4.5.14 would not operate satisfactorily during excitation by the low frequency vibration specified in MIL-STD-167. Resonance of the belt or paper probably would occur. However, satisfactory operation of this recorder under shipboard conditions is expected because of the lower levels of vibration. Perhaps a waiver of MIL-STD-167 for the graphic recorder is in order.

Enclosure (23)

CONFIDENTIAL

Task No. 23

CONFIDENTIAL

I. TASK NUMBER: 24

II. TASK TITLE: Reliability/Maintainability

III. INVESTIGATOR(s): H. J Klee, R. A. Klug (Prepared by G. T. Kemp,TRACOR)

IV. CONCLUSIONS

A. Recommended Changes to Specification

1. On the contract specification:

a. The specification on repair time should be in terms of Equipment Repair Time (ERT) rather than Mean Time to Repair (MTTR). The recommended value for the ERT specification is 20 minutes.

b. The specification should clearly state the confidence required for demonstrating MTBF and ERT unless the proper MILSPECS are invoked which already state these values.

c. Allowable performance degradations should be specified for each mode for the purpose of declaring a mode failure due to degradation. This should include allowable side lobe level increase and bearing accuracy.

d. An indication of the reliability and maintainability demonstration test methods should be given in the reliability section of the contract specification.

e. The recommended values for MTBF specification for the various modes of operation are as follows:

Mode	MTBF Specification*
Active Search	1700 Hrs
Active Track	1390 Hrs
Passive Search	1200 Hrs
Passive Track (Automatic)	920 Hrs
Passive Track (without Automatic)	1100 Hrs
Classification	1220 Hrs

*This recommendation is contingent upon demonstration of reliability by Plan C of MIL-STD-781 and on the mode reliability diagrams attached hereto.

Task No. 24

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2. On Reliability Prediction:

a. Complete redundancy of the CRT displays and of the paper recorders should not be assumed for all modes, but rather only in the two primary modes--active search and passive search.

b. Audio may be assumed redundant with video (but not vice versa) except in the classification mode, where it should be included in the MTBF prediction.

c. Regarding the diagram of Figure 7-7 of Sperry Vol. 1A, a "display buffer" block should be included as a serial item in front of each CRT display.

d. Power supply redundancy should not be assumed if the implementation technique requires a significant down time of the mode for a power supply failure. If this is the case, a mode failure should be declared and repair time (time to get a spare on the line) counted.

3. On Reliability/Maintainability Demonstration Tests:

a. Reliability requirements are presently stated for each separate mode. This mode concept should be carried through demonstration testing and incentive payments.

b. The demonstration test should include checks for degradation in all modes of operation.

c. Invoke sequential reliability test as per Test Plan C of MIL-STD-781, which is designed for a 2:1 discrimination ratio and risks of 10% on both consumer and manufacturer.

d. Invoke a maintainability test as specified in MIL-M-23313, with appropriate minor modifications. In view of the wide variation in skills (with the same experience) of repairmen, it is recommended that 20

repair actions be performed by each of four repairmen and the repair times averaged for each repair action. These 20 averaged repair times would then be used in the framework of MIL-M-23313 for evaluation of the maintainability of the equipment.

B. Suggested Improvements

1. Regarding Sperry Vol. 1A, it appears that the microelectronic integrated circuit failure rate is based on a temperature of 70°C. This should be rechecked in view of Sperry's proposal to go to multifunction chips, where the temperature of the chip will probably be higher, thus lowering the reliability.

2. Clarification of hydrophone failure patterns is needed with regard to possible effects on beam pattern shape and side lobe levels.

3. Since the "Program Generator, System Clock, etc." is used in several modes, it should be considered a critical item for reliability and should be concentrated on from a reliability standpoint.

4. Performance checks on the "receiver" during the reliability check test could be divided into two areas; namely (a) a check on the spatial portion of the receiver (from the water through the beamformer) and, (b) a separate check of the temporal portion using injected signal and noise (from the output of the beamformer through the display).

C. Need for Further Investigation

1. A study is needed which will determine the power handling capabilities (including duty cycle) of the various transducer elements, driver amplifiers and power sources (motor-generator sets).

2. Reliability and maintainability predictions should be evaluated carefully at the various stages of design and manufacture by an independent group.

3. A careful check should be made on the internal manufacturing and quality control inspections of the contractor.

V. DISCUSSION

Essentially the same format will be employed in this section as in the Conclusions.

A.1.(a) According to MIL-M-23313, the equipment repair time (ERT) should be specified in the equipment specification, rather than MTTR. The reason for this is that a confidence interval can be put on ERT, whereas one must assume a value for σ (standard deviation) in order to put a confidence interval on MTTR.

The recommended value for the ERT specification of 20 minutes reflects a maximum acceptable ERT of 54 minutes (see Section 6.4 of MIL-M-23313.) This, in turn, corresponds to a maximum acceptable MTTR of 2 hours under the assumption of $\sigma = .55$.

A.1.(b) A straightforward method of handling the confidence problem is to invoke a self-contained specification for demonstrating MTBF and ERT, such as MIL-STD-781 (with a choice of the proper test plan) and MIL-M-23313A. Each of these specifications clearly state the risks to both consumer and manufacturer as well as the discrimination ratio (the ratio of the specified or design MTBF to the minimum acceptable MTBF or the equivalent for ERT).

NOTE: that in each of these specifications the value of MTBF or ERT specified for use with them is <u>not</u> the value in which one has the specified confidence. However, they are set up such that if the true MTBF or ERT (if tested for a very long time) is as specified, then the test will be passed (except for the manufacturer's risk).

Therefore, due to the very low probability of both displays of either type being down at the same time, the displays should be ignored in calculating MTBF for those two modes. However, any other mode which depends on a particular display would have a declared failure if <u>either</u> display of that type failed. The MTBF predictions should reflect the probability of failure of <u>either one</u> of the two displays. The modes for which this is applicable are:

Active Track

Passive Track

Classification

In view of this suggested change, the specified MTBF for the above three modes should be altered to reflect the change. For example, the failure rate of one CRT and display circuitry is given by Sperry as 11% per 1000 hours. However, the failure rate for both of these displays is 22% per 1000 hours. Combining this with the data in the Sperry Vol. 1A, one obtains the following:

Mode	MTBF	Availability
Active Search	1700	.9993
Active Track	1390 (2000)	.9990
Passive Search	1200	.9990
Passive Track (w/o auto track)	1100 (2000)	.9985
Passive Track (with auto track)	920 (1450)	.9983
Classification	(Needs further investigation)	

A.2.(b) Although the audio may be helpful for using the various modes, it is felt that the only mode which would suffer significant performance degradation is classification.

A.2.(c) The recommended change is due to a change in the proposed circuit. This tends to make the modes more independent, which is good from a reliability standpoint.

A.2.(d) Power supply redundancy is an excellent idea, but the method of implementation should determine whether a mode failure is declared when the supply in use fails. For example, if the spare is automatically switched into the circuit and essentially no down time is incurred, no failure should be declared. However, if it is a matter of observing a fault indication, chasing down the proper cabinet and wiring in a new supply, this is a failure, even though the repair time is short compared to actually repairing the failed supply.

A.2.(e) The recommendation of this section is based on the assumption that stabilization and autotrack are separate functions. Loss of stabilization would degrade fire control information under most sea conditions so that a mode failure should be declared, or some evaluation of the degradation (somewhat subjective or it could be done on a statistical basis) must be made.

If loss of autotrack does not affect fire control information, then it would not be declared a mode failure. However, if a performance degradation can be attached to its loss, this could be used toward declaring a mode failure.

A.3.(a) The reliability or availability of a complete system is difficult to determine because of the employment of several modes of operation which are in many ways independent. For example, failure of a CRT display does not make the system unavailable, but does impair performance from the desirable level. Thus, it is recommended that the modes be used in the determination of MTBF and the resultant incentive payment (see 5 below).

In view of the specification of the same repair time for each mode, it seems appropriate to lump all repair actions together to obtain a system repair time. The same reasoning applies to the times between unscheduled maintenance.

A.3.(b) There are types of component failures in each mode which would not put the mode out of operation, but which would degrade performance. The demonstration test should include periodic checks for performance degradation for comparison with the allowable degradations set forth in the contract specification.

A.3.(c) Sequential (ST) versus Fixed Time Tests (FTT).

There are several subtleties in the statistics of these two types of tests, but only a few of the key points will be presented here in simplified form (a considerable amount of literature is available on both types, the AGREE report being an easily read document regarding sequential testing. Abraham Wald's "Sequential Analysis" is a basic text on the subject).

The essence of the following discussion is to point out that for the information desired for MTBF determination with any specified consumer's and manufacturer's risks and discrimination ratio, the sequential test will yield the answers in about half the time on the average, but never in longer time, than the fixed time test. Therefore, if a certain test time is available, one can either use the same risks and reduce the discrimination ratio below that of an equivalent fixed time test, or hold the discrimination ratio and get a smaller risk on either, or both, parties. This is on the average and any particular case will vary in required test time.

In a FTT, the test time must be specified in advance and the entire test completed for the statistics associated with the test to have meaning.

In a ST, such as those specified in MIL-STD-781, if the failure time curve crosses the accept or reject line, the test is terminated and the statistics still have meaning.

The previous two paragraphs are saying that in the ST, one takes advantage of being able to observe the failure time experience and use it to make an early decision (in most cases), while in a FTT, one is not allowed to do this. Rather, one <u>must</u> wait until the end of the test to make his judgement. The result of this difference is that on the average, the ST can be completed in just over half the time of an <u>equivalent</u> FTT The "equivalent" means the same manufacturer's and consumer's risks, the same discrimination ratio and the same MTBF requirements. Of course, any specific case will vary from the average, but in <u>no</u> case will the ST ever be longer than the equivalent FTT.

It is rather simple to incorporate the incentive payment idea into sequential testing. Basically, one "aims" first at the highest payment (largest MTBF). If he is rejected, he goes for the next lower one, etc. until he is accepted on a particular level.

An example of how the ST is useful may help clarify the concept. If one is testing an equipment against a 500 hr specified MTBF with, say 90% confidence, if he runs for 2500 hours without a failure, one would <u>feel</u> that he had a "winner". The ST would agree, on a sound statistical basis, and the test would be terminated long before an equivalent FTT. On the other hand, if 5 or 6 failures occurred in the first few hundred hours,

one would be suspicious that he had a "loser" and rightfully so. The ST would agree and terminate the test with a reject in a short time compared to an equivalent FTT.

A.3.(d) In general, the maintainability specification MIL-M-23313A is a very good one and covers most of the important points. It clearly states the risks to both parties and states how the risks change if a second test (recommended if the first test is failed) is conducted. The specification is written for 20 repair actions and lays the ground rules for failure simulation.

One area of the MIL specification which is subject to question is the use of only one repairman. The main object of the maintainability test is to demonstrate the maintainability design of the equipment, not the peculiarities of a particular technician. Therefore it is recommended that only 20 failures be simulated, but that these 20 failures be repaired by each of four technicians. It is realized that the K factor adjustment takes some account of experience, but not of innate skills and judgements. The K factor would still be applied to the technicians and their times averaged for use with MIL-M-23313. In this way, the statistics of the specification remain essentially unchanged, whereas if the number of repair actions is increased, several "constants" in MIL-M-23313 would require modification.

B.1. This discussion assumes that the reliability predictions, failure rates, etc. in the Sperry Vol. 1A were made on the basis of the normal RTL micrologic circuit chips, where 70°C was assumed to be the operating temperature. If this be true, then Sperry's proposed change to the multifunction chip would cause a higher chip temperature and thus a somewhat lower reliability.

The increase in the amount of circuitry on the chip and the increase in chip size indicate about a 40% increase in circuit density, but no temperatures are presently known (perhaps Sperry has some idea).

B.2. More information is needed regarding how a failure of a single element will affect the stave response. The Sperry Vo.1A treated the hydrophones as staves which is satisfactory provided an element failure removes the entire stave signal. Otherwise, the degradation is not so severe. Single element failures across the array have little serious pattern effect, but a few stave failures near the array center can cause high side lobes. If the elements can be isolated, this should reduce the hydrophone failure problem to negligible consequences. However, further study is needed in this area.

B.3. This suggesting regarding reliability of the Program Generator, System Clock, etc., is only one example of a critical item for reliability. There are probably, other critical items in the system, which are weighted heavily in determining system reliability.

B.4. The variability and unpredictability of the noise field around the hydrophones makes it very difficult to use a signal injected into the water for evaluating the performance of a processor. It is much more consistent and reliable to use a taped input to the processor for which a theoretical maximum output is known for comparison with actual processor performance.

In addition the performance of the receiving hydrophones, preamplifiers, etc. through the beamformer could be evaluated by injecting a signal in the water and measuring the receiving response pattern periodically during the demonstration test.

C. 1. The need for a study of the power handling capabilities of the entire transmitter section is apparent from the increased duty cycle of the PAIR system. This study should include both a "paper" analysis of the element and also a DUMILOAD test of each type of element and driver amplifier (as they are used in the system). A separate test could be conducted to evaluate the capabilities of the motor-generator set, but care must be taken to simulate the same load impedance as the generator "sees" in actual operation.

C. 2. An independent review of the reliability/maintainability predictions and design is indispensible in catching design errors or flaws in the prediction procedure. The review group can be in the same company, but must be independent of the design group.

C. 3. A review of the Quality Control procedures is just good standard practice to help assure a better product.

It is not very satisfactory to simply specify what the experimental MTBF (test time divided by number of failures) shall be, since then each person reading the specification would have to do a lot of work to find the value in which 10% confidence can be placed. Also, the confidence value is variable with test time.

A.1.(c) Performance degradation is to be expected in the various modes of operation due to certain types of component failures. In order to evaluate a mode failure cause by degradation it is necessary to have specified the degradation which will be allowed. It is equally important to specify either the level from which the performance may degrade or the minimum acceptable performance of each mode.

A.1.(d) The various way in which the reliability specification can be written, such as the MTBF proven with 90% confidence, the required design value or the experimentally determined MTBF from a test, makes it mandatory that the person writing or editing the reliability requirements be aware of the type of demonstration test to be employed.

A.2.(a) In the present Sperry write-up on system dependability, they assume that there is redundancy of CRT displays and also of paper recorders. There is no doubt that the ability to switch from one display to the other is an excellent design feature and merits reward. However, due to the proposed full time use of the various displays by the several modes, it seems that there will undoubtedly be some system degradation caused by a display failure. If reliability is handled on a mode basis, one can choose the primary mode for each type of display and then assume display redundancy for those modes. The recommended primary modes are:

CRT Display	Active Search
Paper Recorder	Passive Search

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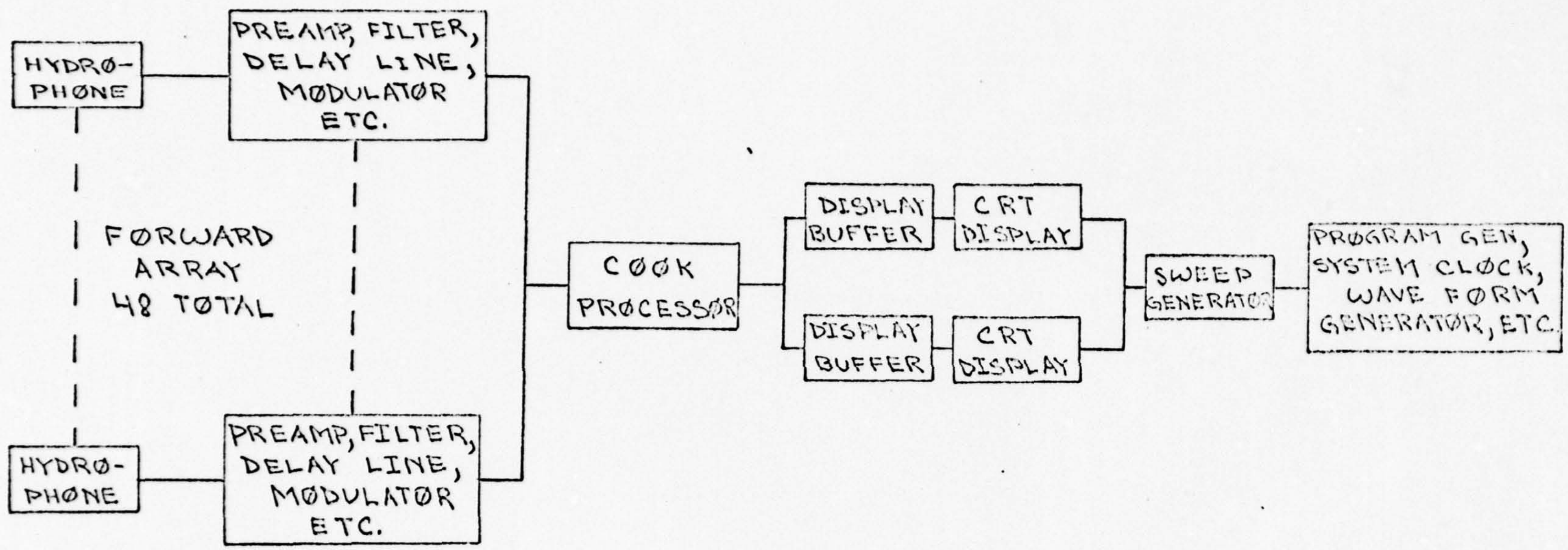

FIGURE 1. RELIABILITY BLØCK DIAGRAM

ACTIVE SEARCH MØDE

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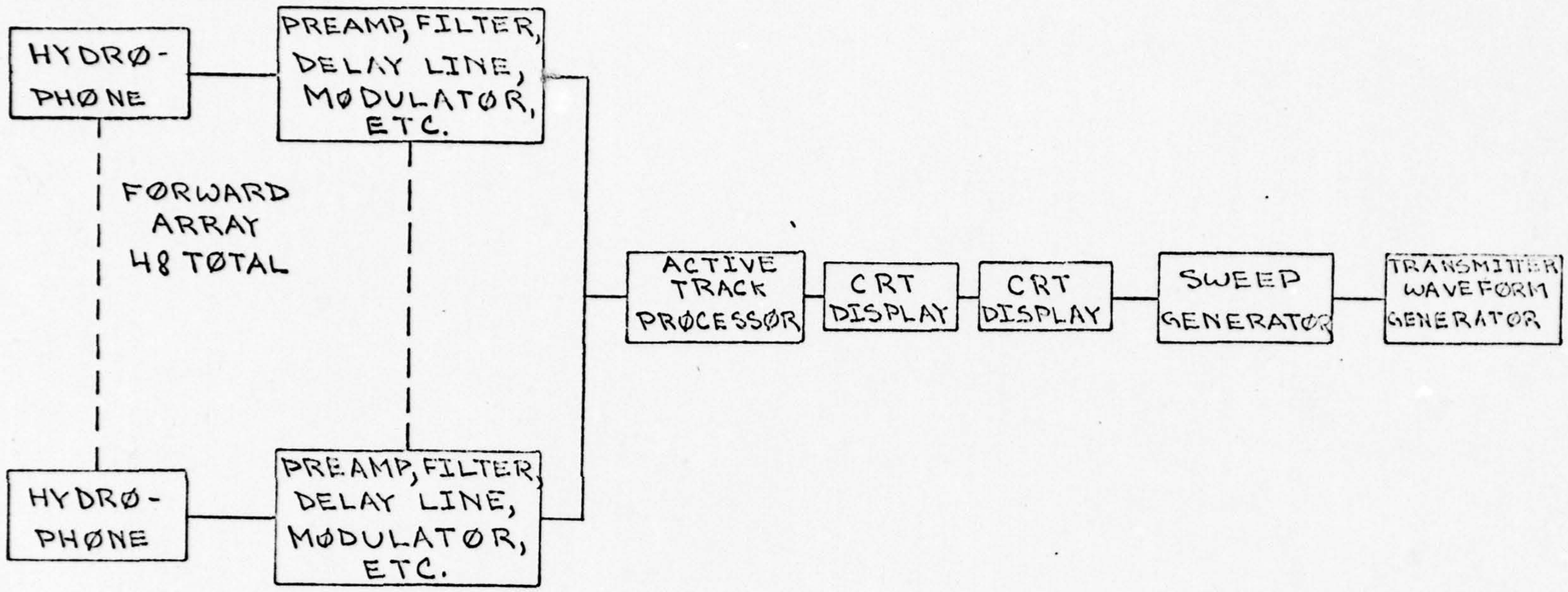

FIGURE 2. RELIABILITY BLØCK DIAGRAM
ACTIVE TRACK MØDE

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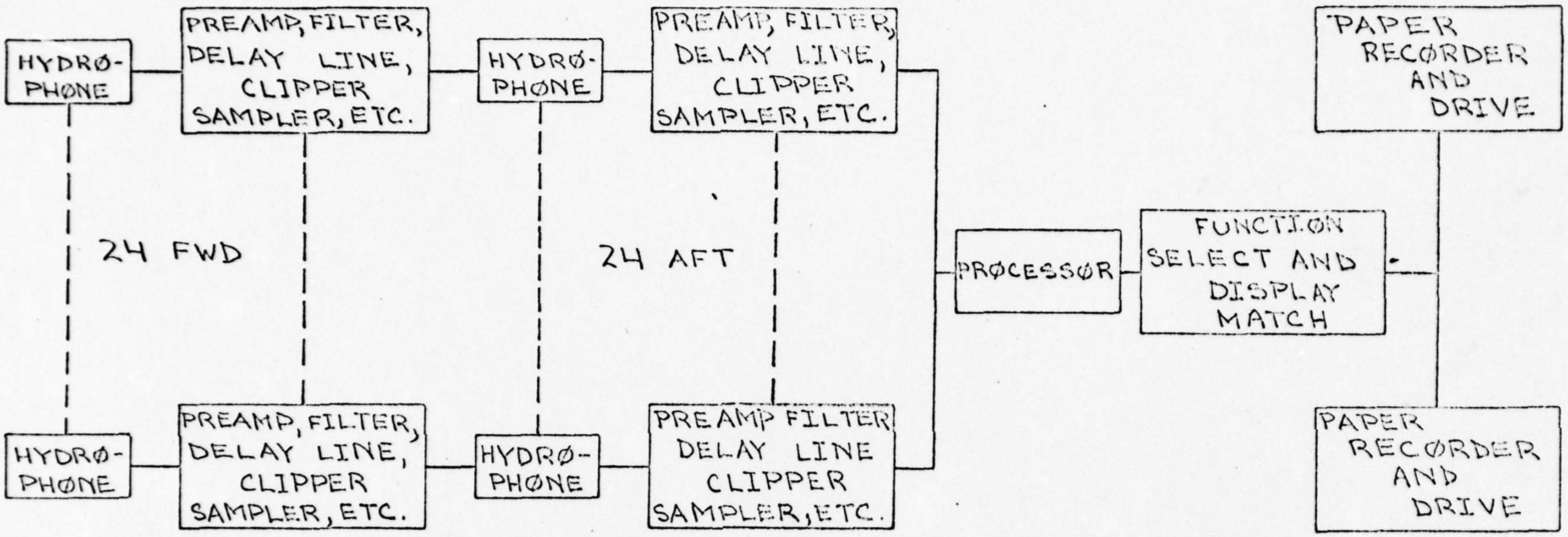

FIGURE 3. RELIABILITY BLØCK DIAGRAM
PASSIVE SEARCH MØDE

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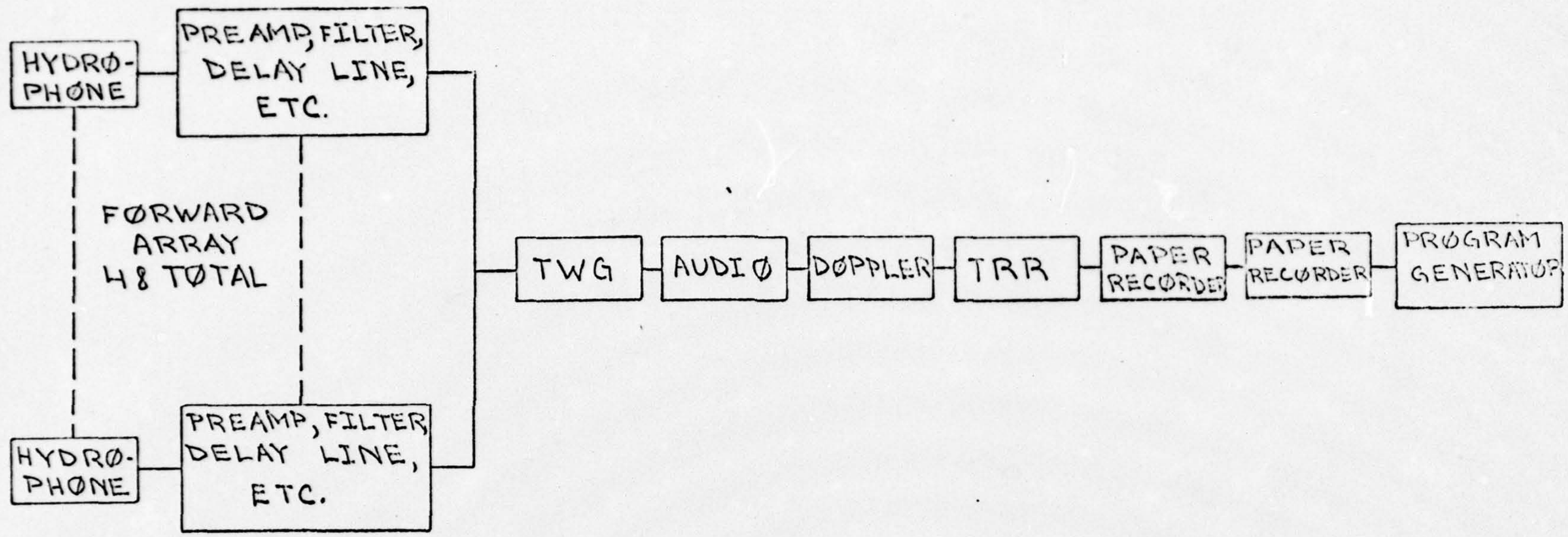

FIGURE 4. RELIABILITY BLØCK DIAGRAM
CLASSIFICATIØN MØDE

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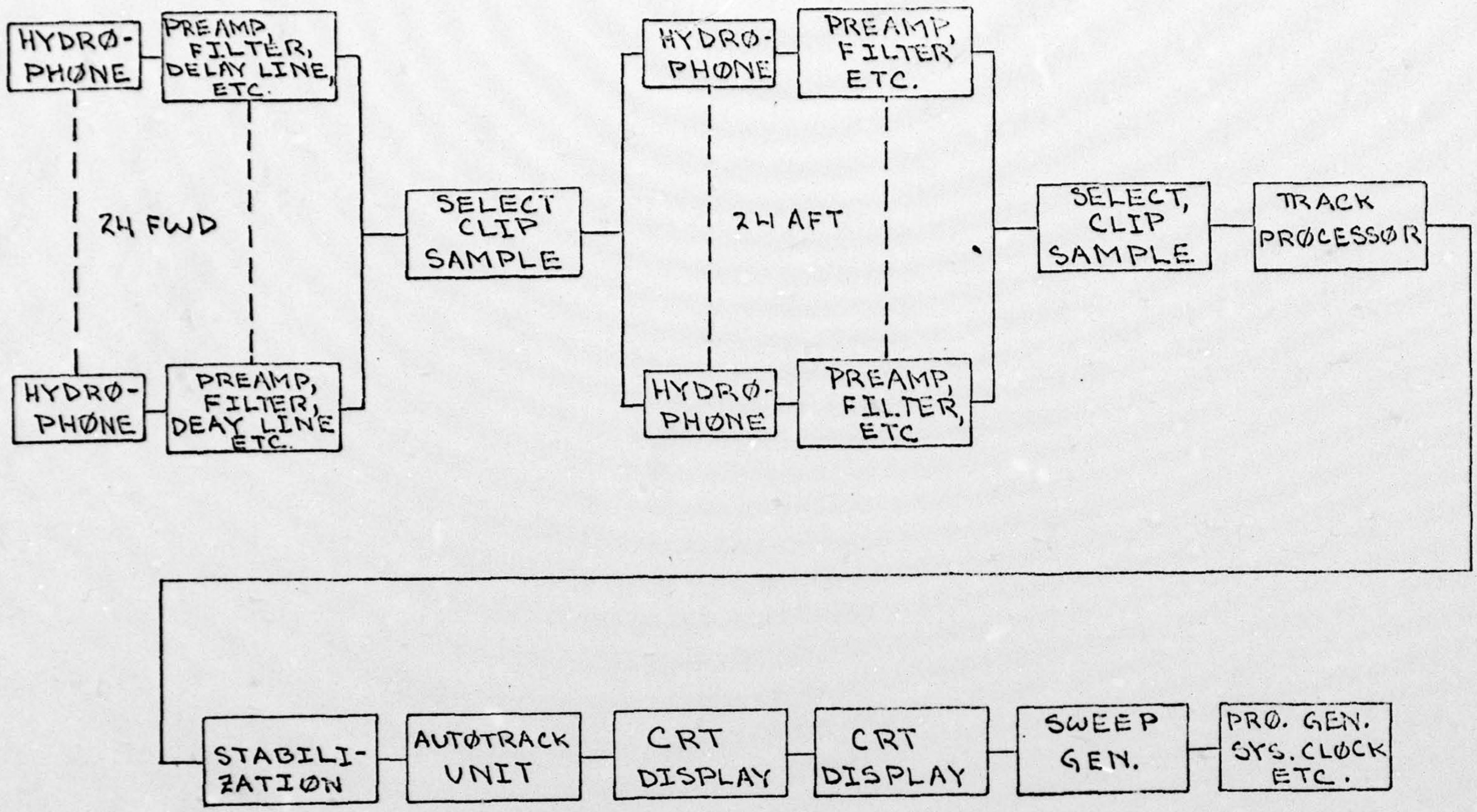

FIGURE 5. RELIABILITY BLØCK DIAGRAM
PASSIVE TRACK MØDE

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I. TASK NUMBER: 25

II. TASK TITLE: Grounding, Wiring Shielding

III. INVESTIGATOR(s): H. Klee, K. Somers and G. R. Potterf

IV. CONCLUSIONS:

A. Recommended Changes

None

B. Suggested Improvements

None

C. Need for Continued Investigation

1. The relative newness of microcircuits in a sonar atmosphere necessitates continued study in the area of magnetic shielding.

V. DISCUSSION

A. Conventional circuits are covered adequately regarding grounding-wiring and shielding by the Military Specifications listed.

B. Microcircuits appear to have been thoroughly investigated by Sperry. The techniques outlined in their study should be adequate (reference attached memorandum 3350-M-541).

Enclosure (25)

M E M O R A N D U M

3350-M-541
7 September 1965

From: G. R. Potterf, Code 3350d
To: Code 1000
Via: Code 3300

Subj: Report of travel to Great Neck, New York during the period of 30 - 31 August 1965

Encl: (1) List of attendees
(2) PAIR logic packages
(3) Fairchild application brief
(4) Memo on hot gas soldering

1. At the request of Code 2140, two members of the NEL micro-electronics laboratory visited the Sperry Gyroscope Company, Great Neck, New York. The purpose of this visit was to gather information on Sperrys' proposed application of microelectronics in the AN/SQS-23 modernization program (PAIR). It is apparent that Sperrys' use of microelectronics in PAIR will be an extension of techniques used in PADLOCK III. Very little finalized design was available for PAIR; most of the material discussed pertained to PADLOCK III circuitry and proposed variations thereof.

2. Sperrys' choice of RTL circuitry for PAIR is apparently based on earlier decisions to use this type of logic in other systems (IHASS, ILASS, Loran-C, PADLOCK III, and others). Four logic functions were chosen: an inverting buffer, a dual two-input gate, a dual three-input gate, and a J-K flip flop. These circuits correspond to the Fairchild Micrologic elements 900, 914, 915 and 926 respectively. Sperry is cross-licenced with Fairchild and Sperry Semiconductor, Norwalk, Connecticut, is a second source for these circuits. RTL circuitry should perform adequately at the speeds anticipated in PAIR (2 mc maximum) as long as good practices are carried out in the design of logic circuits (no data on logic design available).

3. Sperry proposes to continue using Resistor-Transistor Logic for PAIR, but plans to redesign the monolithic circuits to include more functions per package, as shown in enclosure (2). This idea is similar to Fairchilds use of a quad two-input gate and a triple three-input gate in its DTL line. The use of more complex functions per package should increase system reliability in that fewer hermetic seals and interconnections will be required. These more complex functions will be, however, entirely new circuits, and reliability and life test data pertaining to the present RTL circuits may not apply. As a matter of fact, Sperry Semiconductor has not been making

the present RTL circuits long enough to accumulate life test data. Their reliability data so far has consisted of step-stress tests, wherein an attempt is made to correlate parameter shifts with those that result when similar Fairchild units are subjected to the same tests.

4. Sperry Semiconductor is now designing the multifunction circuits, and the first quad two-input gates should come off the line in November. Fairchild and Amelco are also to produce these circuits, using the Sperry design, including chip layout but not necessarily exactly identical masks because of slight processing differences from one plant to another.

5. According to Sperry, the circuits will be mid-range elements and a sliding voltage power supply will be used to make them perform over the MIL temperature range of -55° C to $+125^{\circ}$ C. The supply voltage will decrease linearly from +4 volts at -55° C to +2.5 volts at $+125^{\circ}$ C and in this way the circuits are supposed to meet loading, speed, and noise immunity specifications over the full temperature range. This is a new technique and should be thoroughly tested. See Fairchild application brief #0004, enclosure (3).

6. The choice of Amelco as a source of the RTL circuits apparently is an outgrowth of a coalition of Sperry and Teledyne, of which Amelco is a division, on the IHASS Program. Amelco is not cross-licenced with Fairchild and as yet is not set up to build epitaxial circuits (an engineer at Sperry Semi remarked that he would prefer Philco over Amelco as a source). According to Dan Fisher, Sperry Gyroscope will use from 1.5 to 2 million microcircuits in the next 12 months. Since the output of Sperry Semi is about 20 - 30 thousand per month, it is evident that the greatest number will come from Fairchild. Joe Roediger stated that only a portion of the 1.5 - 2 million would be the multifunction RTL.

7. Grounding, shielding and signal and power distribution are fairly well covered in Vol. 1-A, paragraph 4.4D of the proposal. The RTL circuits are most sensitive to ground noise; 150 mv on ground is about the most noise allowable for reliable operation under worst case conditions. The ground bus used on PADLOCK III is a copper bar, $\frac{1}{4}$" x 3/8", across each card tray, with a vertical bar used to connect the card tray grounds to the power supply. It would appear that the use of these heavy ground busbars, and mu-metal cabinet

shielding to guard against external fields, should keep the noise problem under control. Sperry claims to have had no noise problems in PADLOCK III (as yet untested). Power is also distributed using the heavy copper bars. In addition, each card is to have an R-C decoupling network mounted upon it to suppress switching noise on the power supply lines. PADLOCK III cards, which do not use the decoupling network, have operated correctly with 0.5 volts of noise on Vcc. PAIR, however, will be a much larger system and decoupling is recommended.

8. The number of circuits per board as used in PADLOCK III is any number up to ten, using an 18 pin connector. The number for PAIR cards, where it is intended to use the multifunction circuits, has not been decided upon. Sperry plans to go to a connector with about 34 pins, but the number of packages per board will probably not be significantly different. Sperrys' thinking is to keep card cost down so that they can be thrown away. One hundred dollards ($100.) seems to be the magic number. PADLOCK III uses Cinch edge connectors and these will be used in PAIR also. In PADLOCK, the cards are held in place with a spring-loaded bar across the card try. Cards will be approximately 2" x 3".

9. Attachment of conventional components to the printed circuit board will be done by dip or wave soldering. Flat pack joining will be done by a Sperry technique, hot gas soldering. This process consists of pretinning the leads and printed circuitry and sweat-soldering them together, with a hot gas used to supply the heat. A reprint of an article describing this technique and some comments are enclosed (enclosure (4)). On PADLOCK III boards observed, the process appeared to yield good connections. A slight bending of the leads is necessary, but this is done in a jig which clamps the leads near the body of the package to prevent damage. The leads are clipped to length while in the jig.

10. Analog circuits used in PADLOCK III are of both monolithic and multichip construction. Differential and operational amplifiers are built using a modified Texas Instrument "Master Slice" silicon chip. Sperry Semiconductor is to be a second source. Feedback networks for these amplifiers are thin film (made by Corning Glass) taking advantage of precise resistor ratios. PADLOCK III tests will show how well the specification on these circuits can be met; 0.08 microvolts self noise and 100 db dynamic range will not be easy to achieve. The line driver-standard voltage gate circuit is currently

built in multichip form for PADLOCK III (General Instruments), but may be constructed in monolithic form for PAIR. If so, the circuit would be less expensive in quantity, and more reliable.

11. It appears that the technical goals set for PAIR, as far as microelectronics is concerned, are not impossible to reach. In the digital portions of PAIR, the RTL circuits should be capable of performing at the anticipated speeds (no data on logic design, loading, etc., but if care is taken to observe design rules no problem should exist). Noise will be the greatest problem in this area, but the grounding and shielding efforts demonstrated in PADLOCK III seem to be adequate. The use of a sliding voltage power supply to make midrange circuits useable in a military environment is interesting but needs to be thoroughly tested. Any attempts to apply reliability and life test data on PADLOCK III RTL to the multifunction circuits should be carefully reviewed. In the analog portions of PAIR, the use of monolithic circuits is preferred over chipped-up circuits, from a reliability point of view. The specifications calling for 0.08 microvolts of self noise and 100 db dynamic range for the amplifiers may be difficult to meet. The hot gas soldering technique seems to provide good connections. The number of packages per card and the card size are typical of many microelectronic systems being built today.

G. R. POTTERF

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I. TASK NUMBER: 26

II. TASK TITLE: Torpedo Detection

III. INVESTIGATOR(s): W. E. Klund (Prepared by Dr. B. M. Brown, TRACOR)

IV. CONCLUSIONS

A. Recommended Changes to Specification

None

B. Suggested Improvements

None

C. Need for Continued Investigation

None

V. DISCUSSION

A. The Active Processor

When reverberation levels, noise levels, and target levels are plotted as a function of range for a typical torpedo at $\pm 45^{\circ}$ aspect the torpedo level is found to lie 10 db or more below the levels required for 50% detection using the wave period processor with either FM or CW pulses and the assumption of high doppler. Typical estimates are shown in sea state 4 for a target strength of -15 db in Figure 1. The dashed plots are the 50% detection levels for the specified clutter. The probability that a torpedo will be detected by the active system is extremely low.

B. The Passive Processor

Detection of torpedoes with PADLOC is illustrated in Figure 2. The torpedo radiation levels for the MARK 37 and the MARK 14 used in the Sperry report and the noise levels for a 15-knot destroyer and sea state 4 are shown as well. The 50% detection level is also shown when the ship is self-noise limited and when detection is sea state 4 limited. This plot indicates

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that passive detection to 4 kyd of a quiet torpedo is possible. These estimates of PADLOC performance are within one kiloyard of the examples in the Sperry report.

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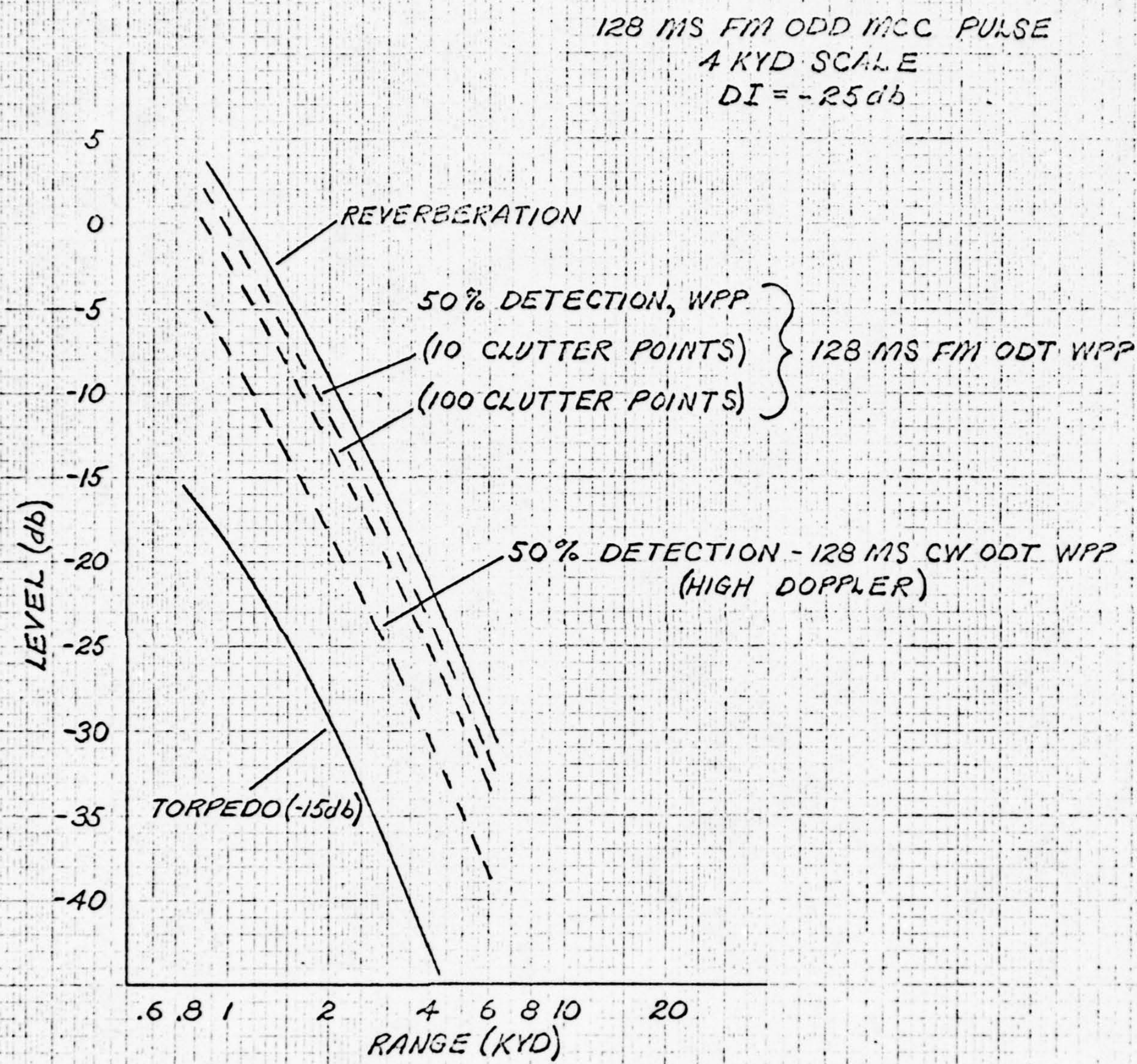

SINGLE PING PERFORMANCE AGAINST TORPEDO

FIGURE 1
TASK 26

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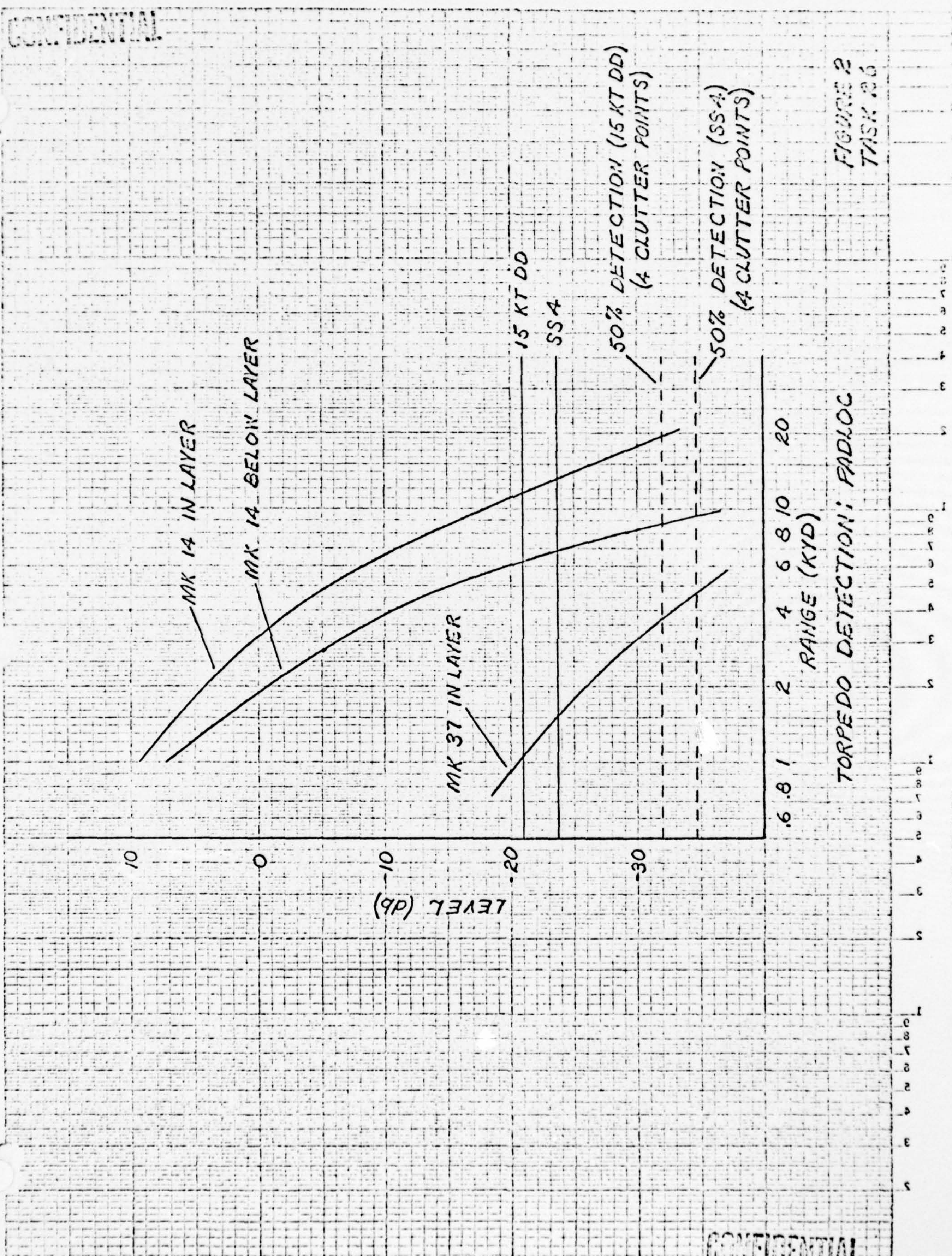

FIGURE 2
TASK 26

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I. TASK NUMBER: 27

II. TASK TITLE: Tracking

III. INVESTIGATOR(s): H. J. Klee and K. D. Somers

IV. CONCLUSIONS

A. Recommended Changes to Specifications

1. Change paragraph 3.3.1.1.4 to read. . . . "shall be less than 0.4° or less and the range error less than 1% with zero target depression angle."

B. Suggested Improvements

None

C. Need for Continued Investigation

1. Investigate the possible tracking error in excess of that specified (0.4° in bearing and 1% of range in the active mode), due to the lack of complete stabilization when the target is at other than zero depression angle. Refer to Task Number 12. A study of how this error affects fire control input accuracy as related to weapon delivery systems should be continued.

2. Further investigation should be made of the tracking data rate supplied to fire control, as a function of the many available ping sequences.

3. Investigate the possibility of improving MCC coverage at close ranges to allow tracking of close targets (Refer to Part V).

V. DISCUSSION

A. Target Aquisition Range of Weapons

1. ASROC and DASH delivered weapons: Information on the most likely used weapons (torpedoes) indicates that they have an aquisition range of 200 yards for a 90% chance of acquiring the target. In the PAIR sonar at a

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range of 20K yards the 200 yard error would require bearing accuracies of $.5^{\circ}$ and a range accuracy of 1.0%. This is within listed specifications of active track. The bearing accuracy using passive tracking is somewhat better than that with active tracking at relative bearings within 65° of either beam.

2. Torpedo; Tube Launched: These weapons will be used at shorter ranges, hence the contract specifications are valid.

3. Hedgehog: The short range of this weapon would allow greater errors in range and bearing, however coverage in the MCC Mode would probably be the limiting factor.

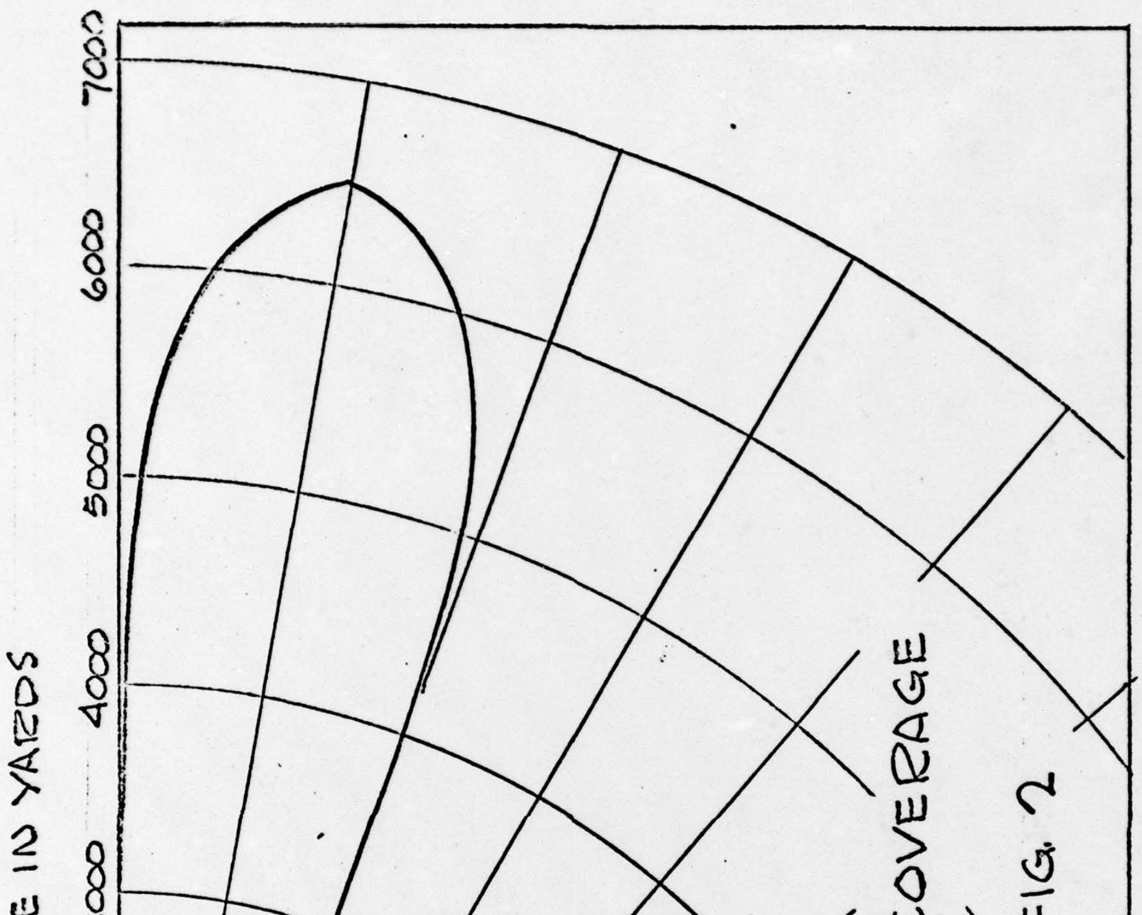
B. The tracking data rate supplied to fire control is a function of ping sequence, and the number of looks necessary to obtain a smooth fire control solution. Selection of the proper ping sequence should be made compatible with necessary tracking data rates. A further investigation is necessary.

C. Maintenance of Close Contact

Figures 1 and 2 show the calculated areas of active transmit receive coverage and lack of coverage due to transmit and receiving beam patterns. The combined transmit-receive beam pattern was computed using the standard sonar equation and the following data:

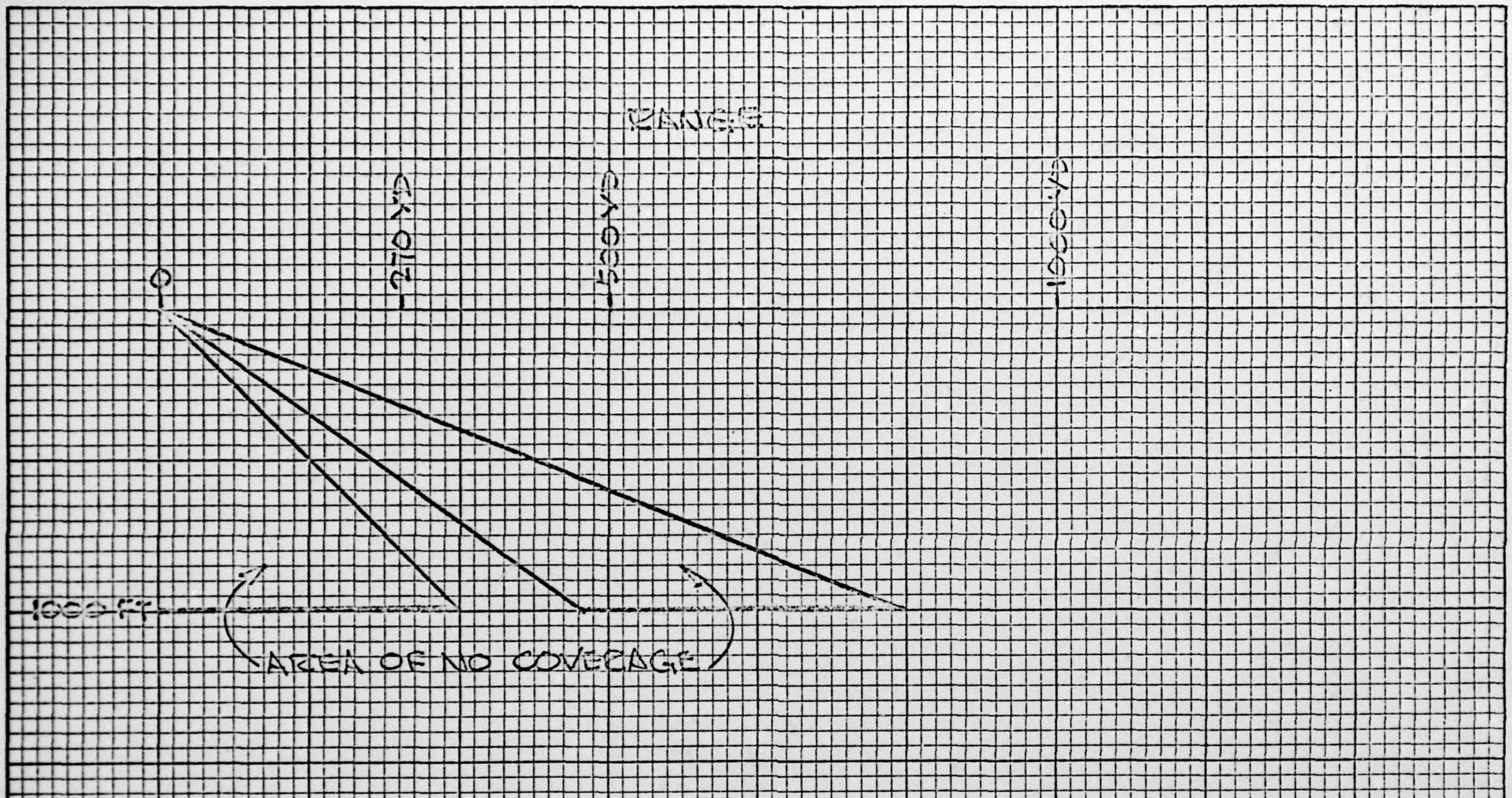
1. Sea State 3
2. Ship's speed, 20 knots
3. Transmission frequency of 5.5 kilohertz
4. Recognition differential - 12 db.
5. A 4 x 48 element ideal transmit beam pattern
6. A Sperry calculated receive beam pattern (Figure 4)

Figures 1 and 2 depict areas of no coverage in the MCC Mode, therefore no tracking information would be sent to fire control for a target in these areas. Further studies on active and passive beam forming should be made to determine whether or not this condition is objectionable.



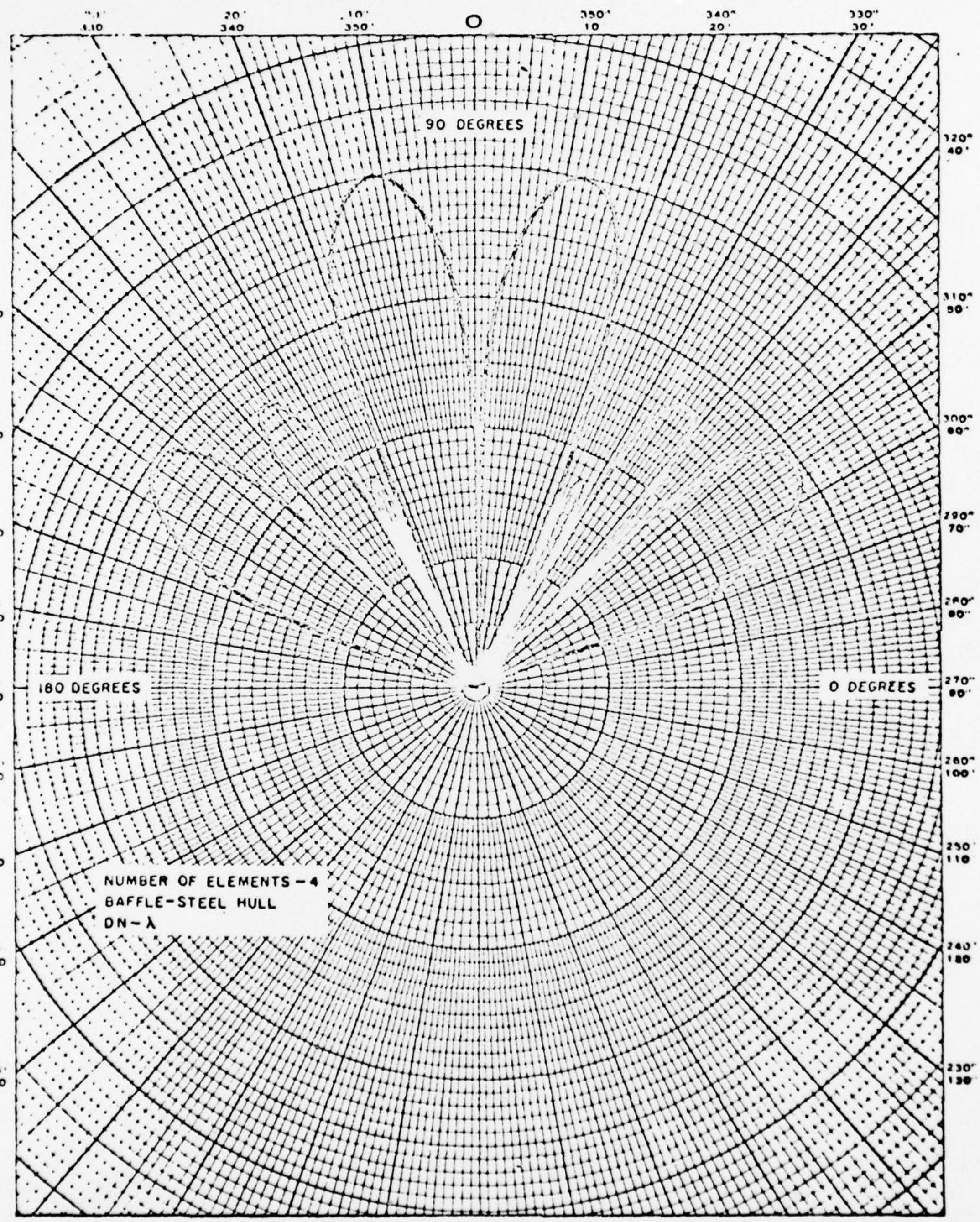
MCC COVERAGE

FIG. 2



MCC COVERAGE

FIG. 1



Task No. 27

Figure 5

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I. TASK NUMBER: 28

II. TASK TITLE: Torpedo Jamming

III. INVESTIGATOR(s): J. Reardon, J. Klisch (BUSHIPS), Dr. Wittenborn (TRACOR)

IV. CONCLUSIONS

A. Recommended Changes to the Specification

None

B. Suggested Improvements

None

C. Need for Continued Investigation

Determine which torpedoes are adversely affected, what harmonics of the sonar affect it, what power received at the torpedo at these harmonics is detrimental, etc.

V. DISCUSSION

Investigations by John Klisch indicate that a problem does exist in this regard on the MK 46 torpedo, but details have not been determined. Dr. G. Wittenborn of TRACOR is investigating the possibility that the Mine Defense Laboratory may have studied this problem. Tests by the Naval Ordnance Test Station in 1960 showed interference by the SQS-23 on the MK 44 torpedo within a range of 1600 yards. (Reference Task Number 16.)

Possibilities to cope with the problem in PAIR are to provide a reduced power capability, reduce the transmitted harmonics, and provide a selectable silent sector on transmit.

I. TASK NUMBER: 29.

II. TASK TITLE: Data Processing Unit

III. INVESTIGATOR(s): J. Reardon, G. Goode

IV. CONCLUSIONS

A. Recommended Changes to the Specification

1. Add "3.4.5.10.4.g) A paper tape reader shall be provided which will allow loading of programs into the DPU core memory from punched paper tape.

2. Add "3.4.5.10.7 - Software

a. Operational Program

(1) The contractor shall supply at least two (2) copies of the DPU operational program on punched paper tape suitable for loading into the DPU core memory.

(2) The contractor shall supply at least two (2) copies of flow charts of the DPU operational program.

(3) The contractor shall supply at least two (2) copies of the DPU machine language printout of the operational program.

b. Diagnostic and fault location program for DPU checkout.

(1) The contractor shall supply at least two (2) copies of a diagnostic and fault location program on punched paper tape suitable for loading into the DPU core memory which will adequately exercise all constituent DPU program functions and isolate malfunctions to the level of the instructions enumerated in Sec. 3.4.5.10.5.

(2) The contractor shall supply at least two (2) copies of flow charts of the diagnostic and fault location program.

(3) The contractor shall supply at least two (2) copies of the DPU machine language printout of the diagnostic and fault location program.

3. Add - "3.4.5.10.8 - Maintenance Aids

a. The DPU shall be equipped with visual readouts, such as neon bulbs or suitable substitutes, showing the contents of at least the following registers:

(1) The register selecting the memory cell which is accessed.

(2) The register containing a word read from memory or to be written into memory.

(3) The principal arithmetic registers.

(4) The principal input/output registers.

b. The DPU shall be equipped with the following manual controls:

(1) A control permitting the program to be advanced by one sequence.

(2) A control permitting the program to be advanced by one instruction as defined in Sec. 3.4.5.10.5.

(3) A control permitting the program to advance until it encounters a jump instruction.

(4) A set of controls permitting the program to advance until a designated address is reached by the program.

(5) A set of controls permitting an inspection and/or change of the contents of any memory cell."

B. Suggested Improvements

None

C. Need for Continued Investigation

None

V. DISCUSSION

The added specifications are necessary to insure that we have the capability to program and maintain the Data Processing Unit, a general purpose stored program computer. The readouts and manual controls specified are typical for such computers.

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GLOSSARY OF ABBREVIATIONS

AGC	Automatic Gain Control
AGREE	Advance Group on Reliability of Electronic Equipment
AU	Arithmetic Unit
Bda[1]	Sonar Train (Stabilized)
CID	Computer Input Data
COD	Computer Output Data
CRT	Cathode Ray Tube
CW	Continuous Wave (refers to a single frequency, time limited pulse)
DD	Detection Display
DPU	Data Processing Unit
DTL	Diode Transistor Logic
EFC	External Function Code
EFL	External Function Line
ERT	Equipment Repair Time
FM	Frequency Modulation (in this text means pulsed 400 cps linear up or down sweep)
FTT	Fixed Time Test
GFE	Government Furnished Equipment
GR	Graphic Recorder
Hertz	Cycles per Second
IAL	Input Acknowledge Line
IDRL	Input Data Request Line
IL	Interrupt Line
I/O	Input/Output

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Kilohertz	Thousand Cycles per Second
LSB	Least Significant Bit
MCC	Maintenance of Close Contact (refers to a double width vertical beam in this text)
MCM	Magnetic Core Memory
MSB	Most Significant Bit
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
NTDS	Navy Tactical Data System
OAL	Output Acknowledge Line
ODN	Own Doppler Nullification
ODRL	Output Data Request Line
ODT	Omnidirection Transmission
OMU	Output Memory Unit
PADLOC	Passive/Active Detection and LOCalization
PAIR	Performance and Integrated Retrofit
PME	Performance Memory Equipment
PPI	Plan Position Indicator
qBa	Apparent Bearing Correction
qRa	Apparent Range Correction
RDT	Rotational Directional Transmission
ROC	Receiver Operating Characteristics
RTL	Resistor Transistor Logic
S	Search
SBR	Steered Beam Receiver
SDS	Sum and Difference Scanner
SLT	Searchlight Transmission

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ST	Sequential Tests
S/T/C	Search-Track-Classify
T/C	Track-Classify
TBR	Time Bearing Recorder
TCD	Target Centered Display
TCU	Timing Control Unit
TRR	Tactical Range Recorder

DTMB	David Taylor Model Basin
LBNSY	Long Beach Navy Shipyard
NOTS	Naval Ordnance Test Station
USNUSL	U. S. Navy Underwater Sound Laboratory

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